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Quantitative assessment of human contribution to risk in nuclear power plants

by

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LIST OF ABBREVIATIONS USED

BWRs	Boiling water reactors
CHRS	Containment heat removal system
CI	Containment integrity
CLCS	Containment limiting control system
CSIS	Containment spray injection system
CSRS	Containment spray recirculation system
ECCS	Emergency core coolant system
EP	Experienced personnel
ESFs	Engineered safety features
ESSs	Engineering safeguard systems
FTA	Fault tree analysis
GPM	Gallon per minute
HE	Heat exchanger
HEPs	Human error probabilities
HPIS	High pressure injection system
HPRS	High pressure recirculation system
LERs	Licensee event reports
LOCAs	Loss of coolant accidents
LPIS	Low pressure injection system
LPRS	Low pressure recirculation system
LWRs	Light water reactors
NPPs	Nuclear power plants
NSRG	Nuclear safety research group
PARR	Post accident radioactivity removal

PAHR	Post accident heat removal
PRAs	Probabilistic risk assessments
PSFs	Performance shaping factors
PWRs	Pressurized water reactors
RCS	Reactor coolant system
RT	Reactor trip
RWST	Refueling water storage tank
SHAS	Sodium hydroxide addition system
THERP	Technique for human error rate prediction
TMI	Three Mile Island

1. INTRODUCTION

A high-technology society places a premium on its demand for energy sources. Of the alternative available energy sources at the present time, nuclear power is one of the most efficient and economical sources. However, there is widespread concern (founded or unfounded) over the safety of nuclear power plants. Much of this concern surfaced as a result of the accident in March of 1979 at the Three Mile Island (TMI) generating station near Harrisburg, Pennsylvania. This accident was the result of a complex set of interactions involving design deficiencies, equipment failure and human errors.

Generally, human performance plays an important role in the reliability and safety of nuclear power plants (NPPs). In order to have a complete safety analysis of nuclear power plants, human reliability considerations are necessary. Several attempts aimed at analyzing the effects of human reliability on NPP system performance have been made in several research projects and safety studies. In particular, the extensive safety analysis work reported in WASH-1400 (1) utilized various human performance data sources and the judgment of technical experts (educated guesses) to provide human error rates. Those sources do not provide actual recorded data. To date, there has been no systematic program to collect human error rates data in operating NPPs. The only formal record of errors in NPPs is in the Licensee Event Reports (LERs), which do not directly yield error rates in the sense of errors per opportunity for error. However, those reports could be used to determine the impact of human errors on the reliability or availability and safety of NPPs.

In NPP operations, certain types of errors of operation, maintenance, and testing can result in the unavailability of some safety-related system or component to perform its safety function for some period of time. This unavailability will continue to prevail until someone discovers that the system or component is not operative, or until the system condition causes other changes to the plant that lead to the discovery of the unavailability of the system. In addition, other events can cause some engineered safety features (ESFs) to be unavailable and may eventually result in some other visible changes in the plant.

In safety analysis, it is often necessary to incorporate human error probabilities into the estimation of component unavailabilities. This may be due to maintenance or calibration errors that can cause one or more components/systems to be unavailable for some interval of time. In such cases, a component's/system's unavailability is a function of the probability of occurrence of some human events, the probability of recovery, and the average time that the component is in a failed condition before being restored. The widely used definition of availability of a system or equipment is the probability that it is operating, or would operate satisfactorily if called upon, at any point in time.

The objective of this research work is to assess quantitatively human contribution to risk in light water reactors (LWRs). Based on WASH-1400 (1), high risk accident sequences are analyzed to select one of those sequences and identify those systems for which in-depth analysis of human contributions are needed. This analysis is utilized here to estimate the effects of significant human action during accident sequences and its resulting impact on LWR safety. The developed human error data banks, which were developed by the Nuclear Safety Research Group (NSRG) at Iowa State University, are utilized to estimate human error rates. Appropriate statistical methods are used to evaluate human error rates and the unavailability of some of the engineering safeguard systems (ESSs) of PWRs due to human errors. Sensitivity analysis of the estimated human error rates are performed to determine those errors which have impact on the overall system reliability.

A review of the previous work in human reliability analysis and its application to nuclear power is presented in Section 2. Section 3 describes some of the performance-shaping factors (PSFs) that affect human reliability in NPP operations. The PSFs determine whether human performance is highly reliable, highly unreliable, or at some level in between. Human performance plays an important role in the safety of NPPs. Some safety aspects of NPPs are presented in Section 4. Section 5 presents the analysis of the selected accident sequence and description of those systems involved in the accident. Systems involved are the containment spray injection system (CSIS), the containment spray recirculation system (CSRS), the containment heat removal system (CHRS) and the sodium hydroxid addition system (SHAS). Since those systems have important involvement, estimation of their unavailabilities due to human errors is presented in Section 6. Estimates of human error rates, based on the developed human error data bank, for valving errors, in the above systems are presented in Section 7. Section 8 presents quantitative evaluation of the systems involved in the sequence reliability and safety characteristics.

2. LITERATURE REVIEW

Safety engineering is the art of protection against potential hazards which may result from use or operation of a device, a system, or a process through design. This involves the design of reliable protective and engineered safeguard systems, of adequate instrumentation and control, of proper accessibility to monitor and observe fluctuations in those parameters which are relevant to the integrity and safety of the system. The light water reactor safety study (WASH-1400) was commissioned to estimate the public risks that could result from the operation of commercial nuclear power plants (1). The risks had to be estimated rather than measured, because there have been no nuclear accidents resulting in risk to the public. The methods used to develop the risk estimates were based on event tree and fault tree techniques, which were used to define potential accident paths and their likelihood of occurrence.

It has been recognized that human factors play a very important role in the availability and reliability of nuclear power plants. For this reason, human reliability considerations are necessary for a complete safety analysis of nuclear power plants. More than 60% of the reported occurrences in nuclear systems involve human factors (2). Human interaction with the system is evident in routine plant operation, testing, and maintenance. Also, human interaction would be required in the event of malfunctions in any part of the plant, including automatic systems. Human errors and other combinations of failures have significantly contributed to the outcome of the TMI-accident (3). Also, the human element played a significant role in mitigating possible consequences of the Browns Ferry accident (4).

In WASH-1400, contributions due to human error have been included in the unavailability of various safety systems for both PWR and BWR. But the study comes short of incorporating adequate modeling of the interrelation between human reliability and the reliability of the systems. This shortcoming has no impact on the final result of this risk evaluation since uncertainties associated with the human errors data are covered by error bands (5, 6). The results in WASH-1400 indicated that system unavailabilities were importantly influenced by the human and his interactions with design. These human interactions can be broadly categorized into two classes: (1) errors committed prior to an initiating event (pre-accident), and (2) errors committed during or following an initiating event (post-accident). In an early study done by Levine (7) on WASH-1400 fault trees, estimates have been made of human error contributions for most of the LWR systems and subsystems evaluated in WASH-1400. For almost one-half of the PWR systems considered, human errors dominated system unavailability and represented from 50 to 95% of the contribution to failure. Further examination of those systems and subsystem fault trees indicates that collectively, errors of a pre-accident nature outweighed those errors committed after an accident by a factor of two.

So far, in the nuclear safety studies, data utilized on human error rates are obtained from sources other than the nuclear industry. A growing effort is now being devoted to analyzing the human error data in LWRs. The need for human factor analysis is related to the necessity to improve the system and, consequently, to avoid the undesired and unscheduled shutdown and to avoid safety systems degradation or unavailability. Human reliability considerations are necessary for a complete safety analysis of nuclear power plants. There is no doubt that evaluation of human error rates based on past experience of the nuclear industry will provide a data base for improving the reliability and safety of nuclear power plants.

Historically, human error rates have been treated in the same way as component failure rates for reliability considerations. Williams (8) suggested this approach and noted that the great difficulty in its implementation has been the unavailability of basic human error rate data on which human task reliabilities could be based. The "Bath

Tub" Shape Curve could be employed for representation of human error rates. The initial decrease in the failure rate is a result of the learning process. An intermediate period represents the constant error rate which is the useful operator life. In this region, only chance failures are considered. The final period of increasing failure rate is due to combination of chance and aging errors. This model applies to a single human operator (9). Although reported data represent a group of people of different ages working under widely varied conditions and stresses at different plants, still human failures can be studied objectively just as can any other component failure (10).

For any task, human errors are best understood in terms of human variability which reflects all factors that may be operating at the time the actions are performed (10). The variability is a characteristic of human performance. The human variability can best be described as the pattern of errors in the completion of a given task. There are three basic types of variability: random variability, systematic variability and sporadic variability. Random variability indicates random errors which are generally due to improper selection of personnel. Systematic variability results in systematic errors. Most often, inadequate feedback leads to a systematic error. Sporadic errors can best be described as chance errors. Human errors leading to catastrophic failures are less frequent than those leading to a delay in operation or a malfunction leading to a shutdown of the reactor. Forced outages of the plant lead to economic loss due to reduction in plant availability. Many factors affect (or shape) human performance in a complex man-machine system such as a nuclear power plant. Some of these factors are external to the person in the system, and some are internal. Those factors are called performance shaping factors (PSFs). Swain and Gultman (11) discuss several of the PSFs that influence the reliability of nuclear power plant personnel. The basic advantages of humans over machines are that humans can perform with higher qualities of perception, recognition and decision-making (5). These qualities are of great importance in operating nuclear power plants. In addition, examination of the nature of human interaction with the system may make it possible to provide means of reducing human errors (12).

Swain (13, 14) developed THERP (Technique for Human Error Rate Prediction) to utilize the AIR DATA STORE in evaluating human error contributions to system degradation. The compilation of basic human error rate data was put forth by Altman and his colleagues at the American Institute for Research and was termed AIR DATA STORE (15). The method utilizes probability tree theory to determine mission reliability from individual tasks and their component behaviors. Discrete error rates and operation times are used so that the model could be used to predict the probability of some events within a specified period of time.

Several attempts have been made to determine the human factor contributions to human reliability and safety of nuclear power plants. Swain (16) has applied THERP to determine human factors contributions to the operational reliability of nuclear power plants. Rasmussen and his co-workers utilized the general features of THERP in the final draft of WASH-1400 (1). Since no actuarial data base for human error rates in nuclear power plants exists, various human performance data sources have been used to provide them. The sources include the United Kingdom Atomic Energy Authority (UKAEA), the Danish AEC, and the Imperial Chemical Industries, Ltd. (ICI) of Great Britain. Those sources, although relevant, do not provide actual recorded data but rather provide estimates of human failure rates based on the judgment of technical experts. The above sources predict human performance data based on tasks similar to nuclear plant operation, maintenance, and testing tasks. Another source of human error rates is obtained from weapons production, maintenance and testing tasks which are not entirely similar to nuclear plant tasks.

Emon and Becar (17) presented a method for system reliability analysis developed by Kaman Sciences Corporation known as Go. This technique was specifically utilized to evaluate the reliability of High Temperature Gas Cooled Reactor (HTGR) scram system including human interfaces. The Go code is a non-Monte Carlo method utilizing probability tree analysis. All possible operational modes are considered, rather than those producing a specific failure as in the fault tree analysis. The analysis is applied in detail to Fort St. Vrain (18, 19). The Go code was utilized to estimate the effects of significant human action during accident sequences and its resulting impact to HTGR safety. Due to limited time, the study was directed on the Reheater Tube Leak accident. High stress, human error probabilities estimated in WASH-1400 were used with a slight modification to be compatible with HTGR operation. The result of this study indicated that probability of getting such scram is directly dependent on the amount of operator involvement assumed at the start of the accident. Although the human interface effects in the HTGR were found to have little impact on system safety, there could easily be a substantial impact on system availability.

Husseiny et al. (20) have investigated human factor effects on Fort St. Vrain by analyzing occurrences data in the period from January 1974 to March 1975. Mean times between failures (MTBF) were calculated for both routine and vigilance tasks.

Sabri et al. (21) have developed a taxonomy of operation tasks and operator errors to classify human error data of nuclear power plants. The scheme is designed for sorting and storing of failure information in a data library for ease of retrieval by a reliability analysis code. It is suggested that continuous updating and smoothing techniques be implemented to yield time-dependent operator performance data over the operating life of a given plant. Kalman Filter techniques were suggested to smooth the data.

Husseiny et al. (22) developed a model to examine the influence of operator performance on reactor shutdown system reliability. The model provides a tool to monitor the operator response in different operational tasks and also it allows the use of existing data on human response.

Joos et al. (23) developed a computer program which is suitable for sorting and storing the failure information for PWRs and BWRs between June 1, 1973, and June 30, 1975, due to human errors.

The Nuclear Safety Research Group (NSRG) developed a computer data management program for storage, handling and retrieval of information and compiled the data extracted from the Licensee Event Reports (LERs). An operator analysis statistical information system (OASIS) using an alphanumeric encoding scheme of LER records and a general event classification system (GENCLASS) containing more detail description of events were presented. An analysis of the interrelationships between operator and human error rates and different operation parameters was conducted. Several statistical techniques for use in data smoothing and for interpretation of LER statistics were examined, and a linear recursive Kalman filter was obtained for data smoothing, prediction and updating of operator error rates (24).

Khericha et al. (25) reviewed nuclear power plant experience to determine causes, frequency, and duration of forced shutdowns of commercial nuclear power stations. Correlations were made among component failure rates, human factors, plant sizes, reactor types, and plant downtime.

Cho et al. (26) developed a computer system to retrieve historical and current data from LERs. The Weibull probability plotting method was applied to operator error data and it was concluded that this method is suitable for estimating Weibull parameters for operator errors that have occurred during operation. Three commercial nuclear power plants were used to evaluate the computer code and operator errors.

Azarm et al. (27) constructed a model to be used in the prediction of future data for operator error rate for two different types of LWRs (PWRs and BWRs) with respect to power rating and time. Static and dynamic models were estimated based on smoothing the data extracted from LERs. It was concluded that the learning process of BWRs is almost independent of power, but in PWRs the power of the reactor is one of the important factors affecting the learning process.

3. PERFORMANCE SHAPING FACTORS

This section describes some of the factors that affect human reliability in nuclear power plant (NPP) operations. The manner in which a human perceives, thinks about, and responds to the inputs he/she receives depends on what are called performance shaping factors (PSFs). The PSFs determine whether human performance will be highly reliable, highly unreliable, or some level in between. Table 3.1 presents the PSFs that must be evaluated when performing a human reliability analysis (28). In general, PSFs are divided into three classes: (1) those outside the individual, the external PSFs; (2) those that are a part of the individual himself, the internal PSFs; and (3) stresses and stressors.

3.1. External PSFs

The external PSFs are those that define work situations of operators, technicians, maintenance personnel, engineers and others who keep the NPP performing reliably and safely. The external PSFs fall into three general categories: Situational Characteristics (SCs), Task and Equipment Characteristics (TECs), and Job and Task Instructions (JTIs).

3.1.1. Situational characteristics (SCs)

SCs include PSFs that are plant-wide in influence, or that cover many different jobs and tasks in the plant.

Table 3.1. Representative listing of factors that shape human performance

External		
A. Situational characteristics	B. Job and task characteristics	C. Task and equipment characteristics
1. Architectural features	1. Procedures required (writ- or not written)	1. Perceptual requirements
2. Quality of environment: a. Temperature b. Humidity c. Air quality d. Noise and vibration e. Degree of general cleanliness	2. Written or oral communications	2. Motor requirements (speed, strength, precision)
3. Work hours/ work breaks	3. Cautions and warnings	3. Control-display relationships
4. Availability/ adequacy of special equipment, tools and supplies	4. Work methods	4. Anticipatory requirements
5. Manning parameters	5. Plant policies (shop practices)	5. Interpretation
6. Organizational structure (e.g., authority, responsibility, communication channels)		6. Decision-making
7. Actions by supervisors, coworkers, union representatives, and regulatory personnel		7. Complexity (information load)
8. Rewards, recognition, benefits		8. Narrowness of task
		9. Frequency and repetitiveness
		10. Task criticality
		11. Long- and short-term memory
		12. Calculational requirements
		13. Feedback (knowledge of results)
		14. Continuity (discrete vs. continuous)
		15. Team structure
		16. Man-machine interface factors: Design of prime equipment, test equipment, manufacturing equipment, job aids, tools, fixtures.

Table 3.1. Continued

Stressors		Internal
A. Psychological stressors	B. Physiological stressors	Organismic factors
1. Suddenness of onset 2. Duration of stress 3. Task speed 4. Task load 5. High jeopardy risk 6. Threats (of failure, loss of job) 7. Monotonous, degrading or meaningless work 8. Long, uneventful vigilance periods 9. Conflicts of motives about job performance 10. Reinforcement absent or negative 11. Sensory deprivation 12. Distractions (noise, glare, movement, flicker, color) 13. Inconsistent cueing	1. Duration of stress 2. Fatigue 3. Pain or discomfort 4. Hunger or thirst 5. Temperature extremes 6. Radiation 7. G-force extremes 8. Atmospheric pressure extremes 9. Vibration 10. Movement constriction 11. Lack of physical exercise	1. Previous training 2. State of current practice of skill 3. Personality and intelligence variables 4. Motivation and attitudes 5. Knowledge of required performance standards 6. Physical conditions 7. Attitudes based on influence of family and other outside persons or agencies 8. Group identification

3.1.1.1. Architectural features Architectural features refer to the general work area or areas, such as control room, room for equipment to be calibrated in, the room housing the turbines and generators. All these have certain architectural features that can affect human performance either favorably or adversely.

One familiar example in NPPs with both favorable and adverse impacts is the large control room housing the operating panels for two or three reactors. One positive aspect is the fact that, in an emergency, centralized control is facilitated and it is more likely that sufficient qualified personnel will be available right from the start of the emergency. A negative aspect is the generally high noise level, the large number of people present at times, and the possibility of confusion.

3.1.1.2. Quality of working environment The next three situational characteristics in Table 3.1 (temperature, humidity, and air quality; noise and vibration; and degree of general cleanliness) refer to the quality of the environment surrounding the worker. NPPs generally provide a satisfactory environment, but there are exceptions regarding the noise level and the presence of an excessive number of people in control rooms. There are certain areas where a high noise level is to be expected and ear protectors should be worn. However, a high noise level cannot be tolerated in the control room as it can cause irritation and fatigue, which may result in errors (29).

A special problem for certain NPP tasks is that of protection against exposure to radioactivity, especially the need for certain maintenance tasks in a low-radiation environment that requires protective clothing to be worn. No detail study has been done to solve such a problem, but interviews with operating personnel indicate that the clothing is uncomfortable and that a primary motivation of personnel in "rad" environment is to get the job done as quickly as possible and get out (29). This motivation could reduce the level of human reliability.

3.1.1.3. Work hours and scheduling of work breaks There have been many studies of human performance as a function of work hours and scheduling of work breaks. Most of the studies are relevant to production jobs or other work where the work rate is paced by the job. Much of the work in NPPs is self-paced except in response to unusual situations, in which case the workers are fully aroused and involved. The usual findings regarding work-breaks are not applicable, since most of the NPP operators, technicians, and other personnel are performing their duties (autonomously), and their efficiency is not likely to be improved by rigid schedules of rest periods. However, there is an important question about the impact of work hours that are longer than normal. This type of schedule occurs fairly often, as when somebody stays on duty at the end of his shift to fill in for someone in the next shift, or during plant shutdown and startup operations that require the presence of certain key personnel throughout (30).

The following are some suggestions recommended for scheduling work hours beyond the normal work time (31):

(1) Under no circumstances shall one work in a NPP for over 16 straight hours.

(2) There shall be at least a 12-hour break between work periods for any individual.

(3) No one shall work more than 60 hours a week.

(4) No one shall work more than 100 hours in any two consecutive weeks.

(5) Ensure that working an extra shift will not mean that one has been without sleep for 24 hours.

3.1.1.4. Availability/adequacy of special equipment/ tools and supplies The effect of the availability or adequacy of special equipment and tools and of supplies on job performance is often ignored in the industry, in general. Generally, it appears that these items are located and managed in a way to suit tool-crib attendants rather than the people who will use them on the job. This reversal of priorities can adversely affect job performance. For example, if much effort is required to obtain certain tools, the worker will tend to make do with what he has, often to the detriment of his work quality.

3.1.1.5. Manning parameters The manning parameters refer to how many and what kinds of people are used to perform which types of jobs. The experience of people who develop manning tables for military organizations, especially for technical jobs, indicates that unless manning is based on a thorough task analysis of all the tasks to be performed, there will be inadequacies in manning (32). Jobs tend to be defined in conventional terms rather than in terms of looking at the population of tasks and then deriving the jobs from a careful analysis of task demands. In NPPs, there is a natural tendency to carry over manning practices from fossil fuel power plants. While much of this carryover is probably relevant, no systematic study of NPP manning that determines to what extent NPPs have different manning needs has been performed (32). It is good to mention here that there are two differences between the U.S. and European practices: (1) in the type of people assigned to control room functions, and (2) the Swedish practice of having two separate job titles for operating personnel.

3.1.1.6. Organizational structure and action by others A plant's organizational structure and actions by supervisors, coworkers, union representatives, and regulatory personnel often fall into the sociological realm. Some of these actions have technical impact. Probably the most important area is administrative control of the status of safety systems and components (33).

When components or systems are removed from their normal operating status for maintenance or other purpose, proper restoration procedures may not be carried out, or certain necessary safety components or systems may not be available when needed because of oversights or other errors. In NPPs considerable reliance is placed on human intervention to avoid this kind of problem. Thus, the kind of administration control in a plant is very important. If the administration control is tight and the supervisors insist on rigid adherence to the control, the likelihood is small that some valve will be left in the wrong position.

Also, actions by regulatory personnel will have a large effect on plant personnel performance and practice.

3.1.1.7. Rewards, recognition, and benefits These PSFs have at least an indirect influence on the performance of technical jobs. Numerous industrial and social psychology books and research papers discuss the importance of these factors.

3.1.2. Task and equipment characteristics

The task and equipment characteristics are PSFs that are specific to a given task. In order to perform a task analysis, these factors are needed. The following sections describe in general terms the task and equipment PSFs listed in Table 3.1.

3.1.2.1. Perceptual requirements The perceptual requirements in a task are determined by the task and equipment features that convey information to the personnel. Almost all of the perceptual requirements placed on the personnel are visual--reading meters, charts, labels, etc. Auditory requirements are minor, requiring only the ability to hear and recognize various alarms. The crucial requirements on the PSFs for displays are that they reliably convey the essential information to the user, and that the display attracts his attention (if prompt response is required).

3.1.2.2. Motor requirements Motor requirements refer to control, adjustment, connecting, or other actions, normally performed with hands or feet. Speed of movement is rarely a problem in NPPs, although the strength required to operate a control device can be a problem in some maintenance tasks. High precision of motor response is not a problem in NPPs, except for certain operations performed during refueling and rod manipulations. Most of the human factors problems in the design of controls in NPPs are related to the use of unnecessarily large control handles and to the poor location and labeling of controls (34).

3.1.2.3. Control-display relationships The relationships between controls and displays refer to the compatibility of displayed information with the required movement of controls. Certain displays lead to certain expectancies as to how a control should be moved. If the displays and their associated controls violate these expectancies, the probability of human error will be very high, especially under stress (35).

3.1.2.4. Anticipatory and interpretation requirements Anticipatory requirements refer to tasks in which a person has to be alert for some signal while performing another activity that also requires attention. Humans have definite limitations in this area. The human is essentially a single-channel mechanism; that is, he/she can pay attention to only one thing at any instant in time. With practice, he can rapidly switch his attention among several stimuli, and it may appear that he/she is attending to several things simultaneously. Still, at any given moment, he/she is attending to just one stimulus.

Interpretation requirements in NPPs are related to situations in which the present information requires some mental processing. This means that the course of action implied by the information is not obvious, and interpretation of the data is required. The more interpretation that is required, the longer the response time and the greater the probability of error.

3.1.2.5. Decision-making and complexity The need to make decisions in a job can help keep the job interesting and challenging. Without any requirement for decision-making, most people become bored. Therefore, the best designed jobs and tasks include the need for a person to use his decision-making ability. Problems for human reliability arise when the information presented to the decision-maker does not adequately support the kinds of decisions he needs to make (34).

The complexity of a job is a function of the amount of information the worker must process and the amount of abstract reasoning or visualization required. Obviously, errors will be frequent if the job is too complex. Tasks in an NPP ordinarily are well within the capabilities of the workers. The experienced operators understand the work of the plant, and they process information at a self-determined pace. However, in some plants the emergency procedures (such as those for LOCAs) introduce complexities that exceed the capabilities even of highly skilled operators.

3.1.2.6. Frequency and repetitiveness The frequency and repetitiveness of human actions are PSFs that have a dual relationship to human performance. Although the ability to perform reliably increases with the frequency and repetitiveness of a task. Highly repetitive tasks become boring and few workers will do their best on such jobs. The optimal tradeoff between reliability and boredom in the design of jobs remains unsolved in many industries, including NPPs. Some calibration tasks, for example, involve so much repetition that it is a tribute to the patience of the technicians that so few errors are made.

3.1.2.7. Task criticality The criticality of a task as perceived by plant personnel will affect how much attention they devote to the task. This is true during time of stress or fatigue when one does not have the time or the ability (energy) to perform all tasks. A person at work will naturally care more about those tasks that are considered most critical to the job. A person's perception of what is critical is influenced by instruction from their supervisor and by the "old hands" with whom he/she works.

3.1.2.8. Memory and calculational requirements These requirements can often degrade human performance. Although long-term memory for facts is not one of man's outstanding capabilities, he does have a good capacity for remembering principles, strategies, and other rules and their applications.

Short-term memory is notoriously unreliable, yet many jobs place unrealistic demands for short-term memory on the personnel. Short-term memory is less reliable than long-term memory because it lacks the long learning time and rehearsal associated with the latter.

The performance of even simple arithmetic accounts for many errors in technical work. This is in part because short-term memory is often involved, especially in the performance of mental arithmetic involving more than two single-digit numbers.

3.1.2.9. Feedback   Feedback, a term borrowed from engineering technology, refers to the knowledge of results that a person receives about the status or adequacy of his outputs. Without the feedback loop shown in Fig. 3.1, a worker operates as an open-loop system and cannot perform complicated activities reliably (36).

3.1.2.10. Continuity   The term continuity refers to the extent to which each task element is a discrete step, e.g., typical calibration or maintenance procedures or non-discrete (i.e., continuous) (36). Continuous tasks involve some sort of tracking activity in which the operator monitors some continuously changing situation and takes appropriate control action. In NPPs, rod control during startup or shutdown is an example of a continuous task. The operator's control actions associated with such tasks can be either continuous (as in a rod control) or discrete (as in stopping a pump when the water level reaches some point).

3.1.2.11. Team structure   This term refers to the combinations of people performing work that must be done by two or more persons. The most important point concerned

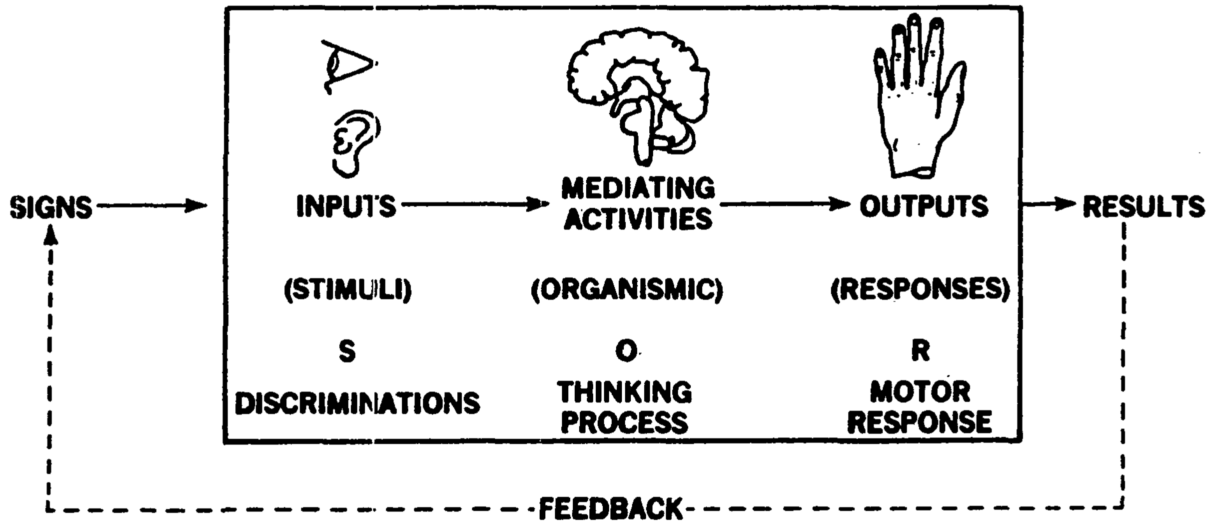


Figure 3.1. Human operator in a feedback system

here is the technical aspects of people working in teams. The major technical aspects has to do with the recovery factors made possible by having one person in a position to observe another's work either during or after completion of the work.

3.1.2.12. Man-machine interface factors This term covers all points of contact between human and hardware. It includes test equipment, handling equipment, tools, etc. More discussion of this term is given in Swain (37).

3.1.3. Job and task instruction

The PSF job and task instructions include the written or nonwritten procedures followed in performing the work, written or oral communications, cautions and warnings, work methods, and plant policies. Although all of these PSFs are important for reliable human performance, this discussion will be directed mainly towards written procedures and work methods.

One of the most important work methods is the correct use of written procedures, especially checklists. If any task is performed without step-by-step reference to written procedures, errors of omission are much more likely. If a checklist is used improperly, as when someone first inspects several items of equipment for proper status and then checks the checklist items all at once, errors of omission are again very likely.

It is recognized that well-written procedures and good work methods can often compensate for less-than-adequate human engineering of equipment. Yet, the written instructions in NPPs do not conform to established principles of good writing; they are more typical of military maintenance procedures of approximately 20 years ago (38).

Written procedures that are difficult to read, difficult to locate, or inconvenient to use are seldom used. At some plants, emergency procedures are not easily distinguishable from the other procedures; and, once located, a specific emergency procedure within the procedures manual is difficult to find because there are no tabs or other indexing methods to assist the operator. Finally, the format and content of the typical NPP procedures are not easy to use. One of the most serious problems with NPP emergency procedures is that there are too many instructions that are not safety-relevant. Much of this safety-irrelevant information concerns the reduction of monetary loss (38).

3.2. Stressors

Stress can be psychological, physiological, or both. Sometimes it is not possible to differentiate between the two. A stressor can be defined as any external or internal force that causes bodily or mental tension. One may recognize that stress appears to arise whenever there is a departure from optimum conditions which the organism is unable, or not easily able, to correct (39).

3.2.1. Psychological stress

Table 3.1 lists some psychological stressors. Some of these are clearly undesirable, but many are acceptable or even desirable in some limited amount.

Dealing with stress, or even getting people to agree on what stress is, is not an easy task. Fig. 3.2 provides a plot of stress level against performance effectiveness. The plot is not linear. With extremely high levels of stress, the performance of most people will deteriorate, especially if the onset of the stressor is sudden and the stressing situation persists for long periods (40).

The curve also indicates that at very low levels of stress, performance will not be optimum. There is not enough arousal to keep a person sufficiently alert to do a good job. The curve also shows that there is a level of stress at which performance is optimum. This level is difficult to define. It varies for different tasks and for different people. This means that the tasks assigned to NPP personnel should be neither too boring nor so demanding that serious human errors are inevitable. With good ergonomics in the design of plant man-machine interfaces and with properly skilled and practiced personnel, one has the best chance of avoiding

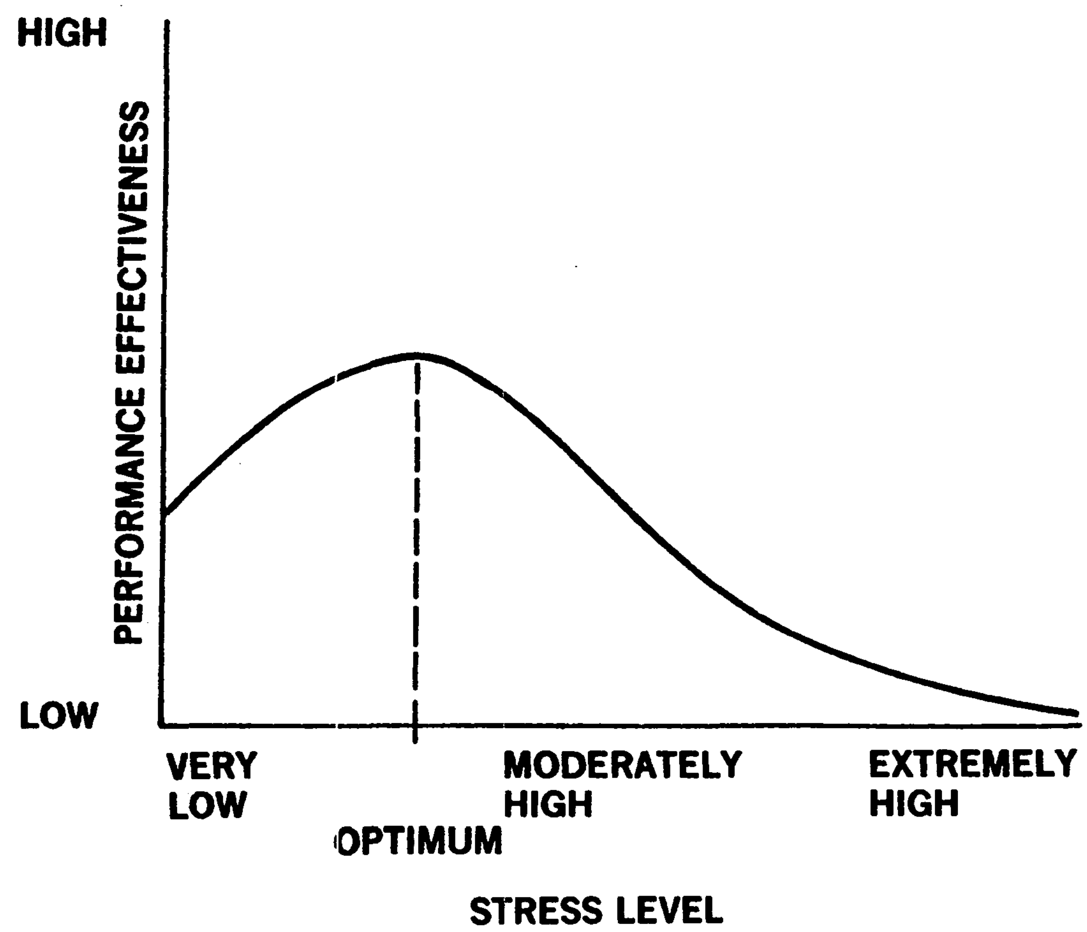


Figure 3.2. Hypothetical relationship of psychological stress and performance effectiveness (40)

the very high end of the stress curve.

The low end of the stress curve has important implications for monitoring tasks. If a control room operator is not sufficiently aroused, he/she is less likely to detect deviations from normal until they result in some annunciated indications. As an example, if an operator's first indication of something untoward is an annunciated signal, he may not always be able to correct the situation on a timely basis. This is in part a design problem, but it is also a problem of ineffective monitoring that develops when the operator is not experiencing enough signals to maintain arousal or alertness. This relative lack of arousal is called the vigilance effect, as shown in Fig. 3.3 (41).

In summary, the effect of psychological stress in NPPs is a serious problem. It can be addressed effectively through a combination of sound equipment design, frequent practice, and responsible supervision.

3.2.2. Physiological stress

Table 3.1 lists some physiological stressors. All of these stressors would be disruptive. The disruptive effects of fatigue, especially as they relate to working beyond a normal 8 hours, were addressed in Section 3.1.1. The special problem of working in a low radiation environment was also mentioned.

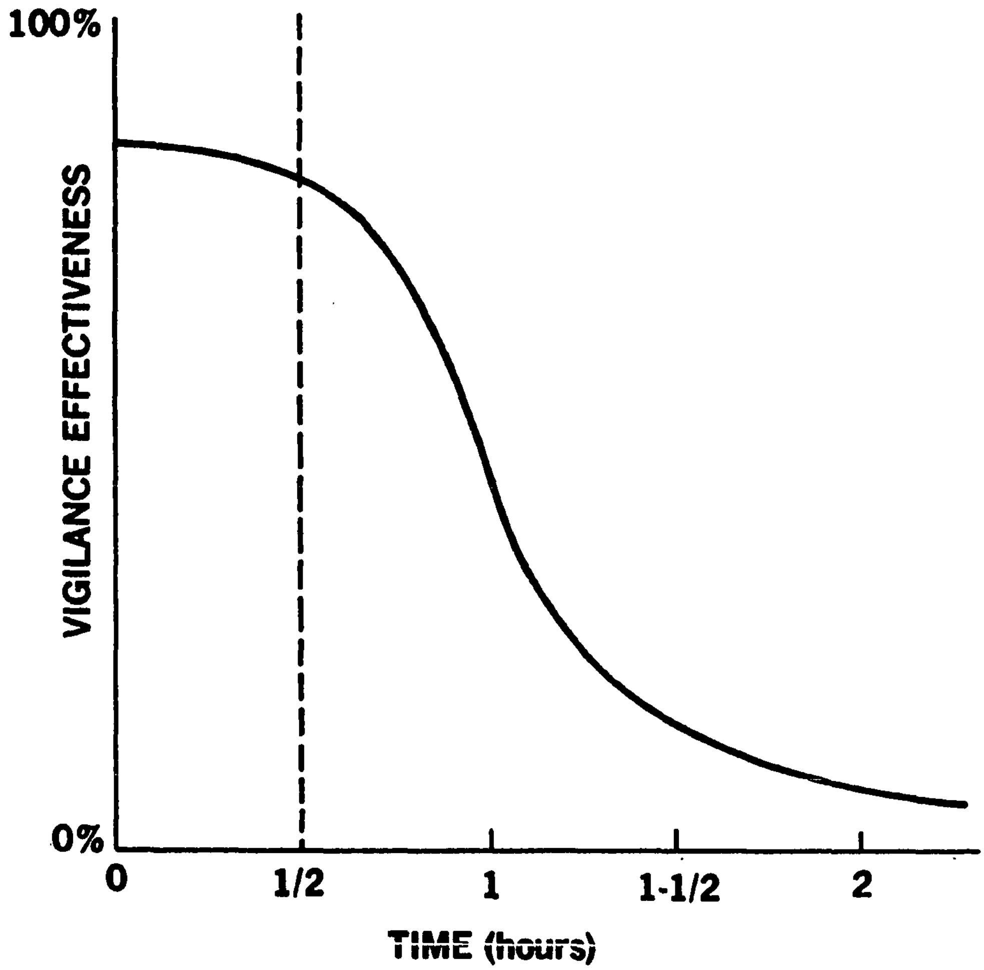


Figure 3.3. Vigilance effect for passive tasks with low signal rate (41)

Few of the other stressors constitute serious problems in NPP operations. However, discomfort can be a highly disruptive PSF for certain maintenance tasks. Errors, especially errors of omission, can be expected to increase if such discomfort is combined with temperature extremes.

Movement constriction and lack of physical exercise is a problem primarily in the control room. However, it is common practice for operators to walk around frequently not only to monitor displays but probably just to get up and move around. Some designers of NPPs have misapplied this small problem of movement constriction and have argued that a standing operator is more effective than a seated one.

3.3. Internal PSFs

Table 3.1 lists some of the contributing factors of the individual in a man-machine system. Some of these PSFs are outside the control of supervision and management, but most are either the direct responsibility of the utility or can be influenced by utility policy.

A number of reports talk about the training of NPP personnel. It was mentioned in WASH-1400 (1) that the level of training of NPP personnel was outstanding. But other reports stated that this judgment should be modified, and it is still believed that the training of NPP control room operator is good, but there is much room for improvement (42).

While there may be some reservations about the quality of training, there is a definite concern about the state of current practice on skill of safety-related task. Interviews with operating personnel indicate that they get very little practice in coping with simulated emergencies (42). Their original training includes valuable practice on dynamic simulators, but once they are assigned to a utility, it is apparently assumed that what they learned on the simulator will remain with them unless they are retrained.

Fig. 3.4 shows the general shape of the curve for loss of ability to cope with emergencies that occur in the absence of practice (the solid line) compared to the continuing improvement that takes place with periodic practice (the dotted line). The time intervals for periodic practice by NPP personnel would have to be determined empirically (43).

An important part of the training could consist in large part of talk-through of emergencies and other abnormal events. No doubt that the operator's ability to respond properly under highly stressful conditions could be modified if talk-through of these tasks were practiced frequently (43).

Although personality and intelligence variables obviously influence human reliability in NPP, these variables are not as important as are other PSFs, especially those related to practice of skills.

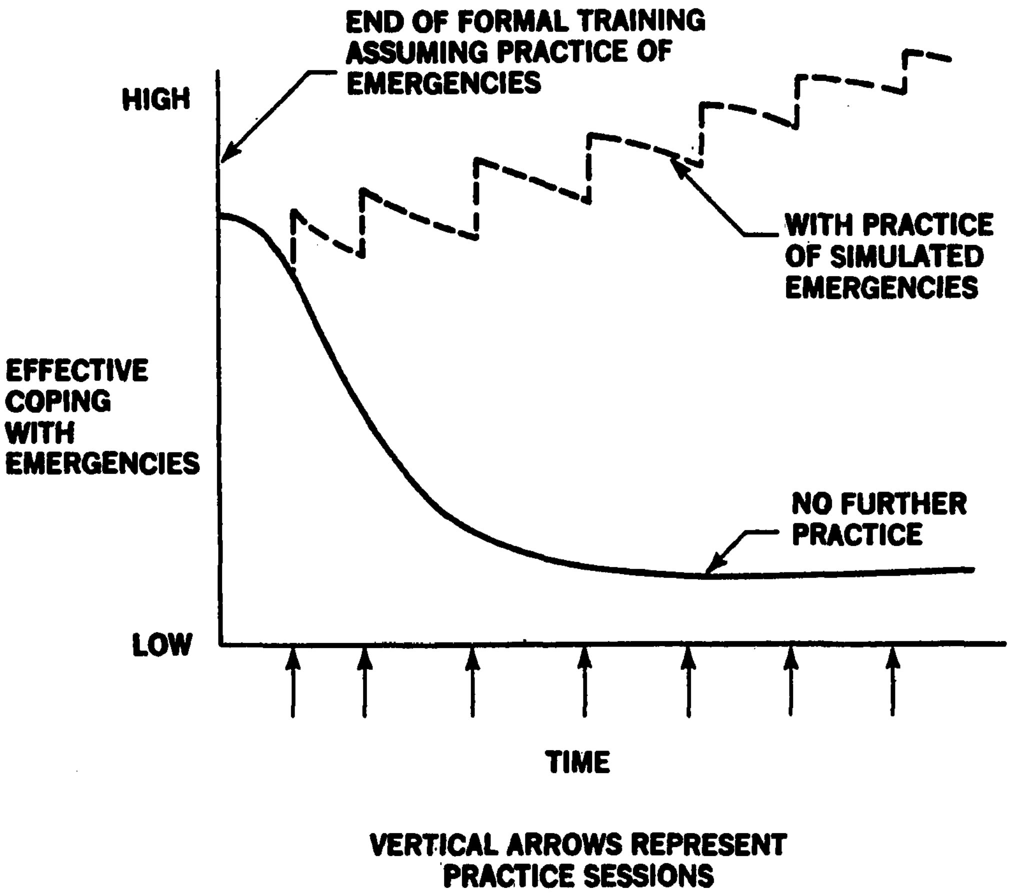


Figure 3.4. Hypothetical effects of practice and no practice on maintenance of emergency skills (43)

The motivation and attitudes of the individual in an NPP obviously have considerable influence on how well he performs. It is known that a well-human-engineered work situation plays an important role in operator acceptance of an enthusiasm for his work. Thus, application of sound human factors practices to NPP design and work operations would have a substantial effect on operator motivation and attitudes.

3.4. PSFs and its Effect on Human Reliability

In summary, many factors affect or shape human performance in a complex man-machine system such as an NPP. Some of these factors are external to the person involved and some are internal. The general work environment influences human reliability, especially equipment design and written or oral work procedures. The individual himself brings to the job certain skills, motivations, and expectations that influence his performance for better or worse. Finally, psychological or physiological stresses can arise to the extent that there is some mismatch between the demands of the work situation and the individuals capabilities.

To perform a human reliability analysis, an analyst must understand those PSFs that are most relevant and influential in the jobs studied. An example will be given here to show how PSFs affect human error probability and consequently the human reliability. This example is demonstrated in Table 3.2 for experienced personnel (EP) and Table 3.3 for novices (11). Novices are considered to be NPP personnel with less than 6 months experience in the job category for which they are qualified. The tabulated HEPs are given in Appendix B.

Table 3.2. HEP per demand and uncertainty bounds for the 4 levels of stress for experienced personnel (EP)

Stress level	HEP	Uncertainty bounds
a. Very low	2 x tabulated HEPs	2 x tabulated values
b. Optimum	Tabulated HEPs	Tabulated values
c. Moderately high:		
1. Step-by-step tasks	2 x tabulated HEPs for optimum	2 x tabulated values
2. Dynamic tasks	5 x tabulated HEPs for optimum	5 x tabulated values
d. Very high	.25	.03 to .75

Table 3.3. HEP per demand and uncertainty bounds for the 4 levels of stress for novices

Stress level	HEP	Uncertainty bounds
a. Very low	Same as EP	Same as EP
b. Optimum:		
1. Step-by-step tasks	Same as EP	Same as EP
2. Dynamic tasks	2 x HEPs for EP	2 x values for EP
c. Moderately high:		
1. Step-by-step tasks	2 x HEPs for EP	2 x values for EP
2. Dynamic tasks	2 x HEPs for EP	2 x values for EP
d. Very high	Same as EP	Same as EP

As it was mentioned earlier, this section presents an example to show how PSFs affect human error probability.

This example is concerned with an operator of a NPP who fails to initiate the task of changing or restoring valves. Using the data given in Appendix B (Table B.2), the HEP for this task is 0.001. Using the information given in Tables 3.2 and 3.3, the HEP for this task for levels of stress is summarized in Tables 3.4 and 3.5.

Table 3.4. HEP per demand for an EP fail to change or restore a valve for the 4 levels of stress

Stress level	HEP	Uncertainty lower bound	Uncertainty upper bound
a. Very low	0.001 x 2 = 0.002	0.001	0.004
b. Optimum	0.001 x 1 = 0.001	0.001	0.001
c. Moderately high			
1. Step-by-step tasks	0.001 x 2 = 0.002	0.001	0.004
2. Dynamic tasks	0.001 x 5 = 0.005	0.001	0.025
d. Very high	0.250	0.030	0.750

Table 3.5. HEP per demand for novices fail to change or restore a valve for the 4 levels of stress

Stress level	HEP	Uncertainty lower bound	Uncertainty upper bound
a. Very low	0.001 x 2 = 0.002	0.001	0.004
b. Optimum			
1. Step-by-step tasks	0.001 x 1 = 0.001	0.001	0.001
2. Dynamic	0.001 x 2 = 0.002	0.002	0.002
c. Moderately high			
1. Step-by-step tasks	0.002 x 2 = 0.004	0.002	0.008
2. Dynamic tasks	0.005 x 2 = 0.010	0.002	0.050
d. Very high	0.250	0.030	0.750

4. SAFETY ASPECTS OF NUCLEAR POWER PLANTS (PWR)

4.1. Introduction

Nuclear power plant safety features differ from those in conventional power plants since nuclear plants may potentially release radioactivity to the environment in case of an accident. While very large amounts of radioactivity are generated by the fission process, the bulk of the radionuclides remains in the fuel as long as the fuel is adequately cooled and the integrity of the fuel elements is protected. For large amounts of radioactivity to be released, the fuel must be severely overheated, leading to essentially clad damage. Based on this fact, various pathways that have the potential for large release of radioactivity to the environment have been recognized (1). Attempting to prevent such accidents and to mitigate their potential consequences has been the primary objective of nuclear power plant safety.

The safety approach for nuclear power plants has often been described as consisting of the following three levels of safety (44):

(1) the design for safety in normal operation, providing tolerances for system malfunctions;

(2) the assumption that incidents will nonetheless occur and the inclusion of safety systems in the

facility to minimize damage and protect the public; and

(3) the provisions of additional safety systems to protect the public based on the analysis of very unlikely accidents.

The safety design approach has also been described as involving the use of physical barriers (fuel, fuel cladding, coolant system, containment building) to attempt to prevent the release of radioactivity to the environment. Some of these safety aspects will be given and discussed in relation to the pressurized water reactor (PWR). The reason for doing so is to give an idea about the nature of NPP accidents and how to mitigate their potential consequences.

4.2. PWR System Description

The PWR was one of the first types of power reactors developed commercially in the United States. This type of reactor has also become standard on nuclear-powered submarines. PWRs operate at a pressure of 2250 psia and have steam generator heat exchangers outside the reactor vessel. At this pressure, water can be heated to about 650^{o}F without boiling. In the steam generators, the high pressure reactor coolant water circulates through tubes whose outer surface is in contact with a second stream of water returning from the turbine condenser. The latter water stream is at a considerably lower pressure and temperature than the former, and heat transferred from the hot water inside the tubes causes the water of the secondary side to boil and produce steam for the turbine.

The primary coolant pumps circulate the water through the primary coolant system, that is, between the reactor and the steam generator as is shown in Figure 4.1. Because the pumps must operate at high temperatures and pressures, and because they do circulate water which is somewhat radioactive, the stringent design and manufacturing criteria used for the other primary components must apply to the pump.

PWR steam supply systems are equipped with pressurizers to maintain required primary coolant pressure during steady-state operation, to limit pressure changes caused by coolant thermal expansion and contraction as plant loads change, and to prevent coolant pressure from exceeding the design pressure of the entire primary system.

The primary system of the PWR contains a large amount of radioactive material, mostly in the fuel but partly in the coolant. A leak in a pipe could result in the release of considerable radioactive material to the surrounding, so the entire primary system must be installed in a special containment building capable of holding the material, as shown in Figure 4.2. Most present-day PWR containment buildings use either dry containment or ice condenser containment systems.

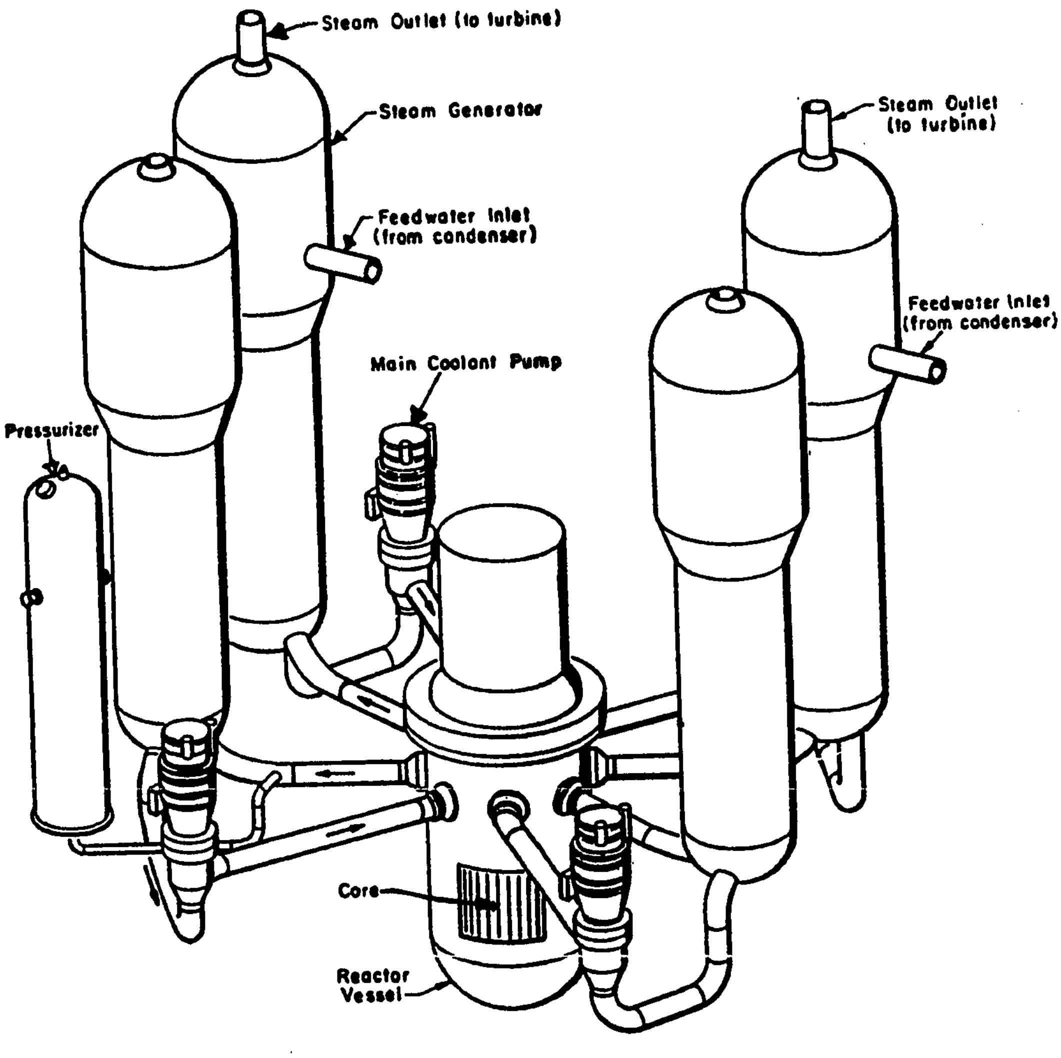


Figure 4.1. Schematic of reactor coolant system for PWR (45)

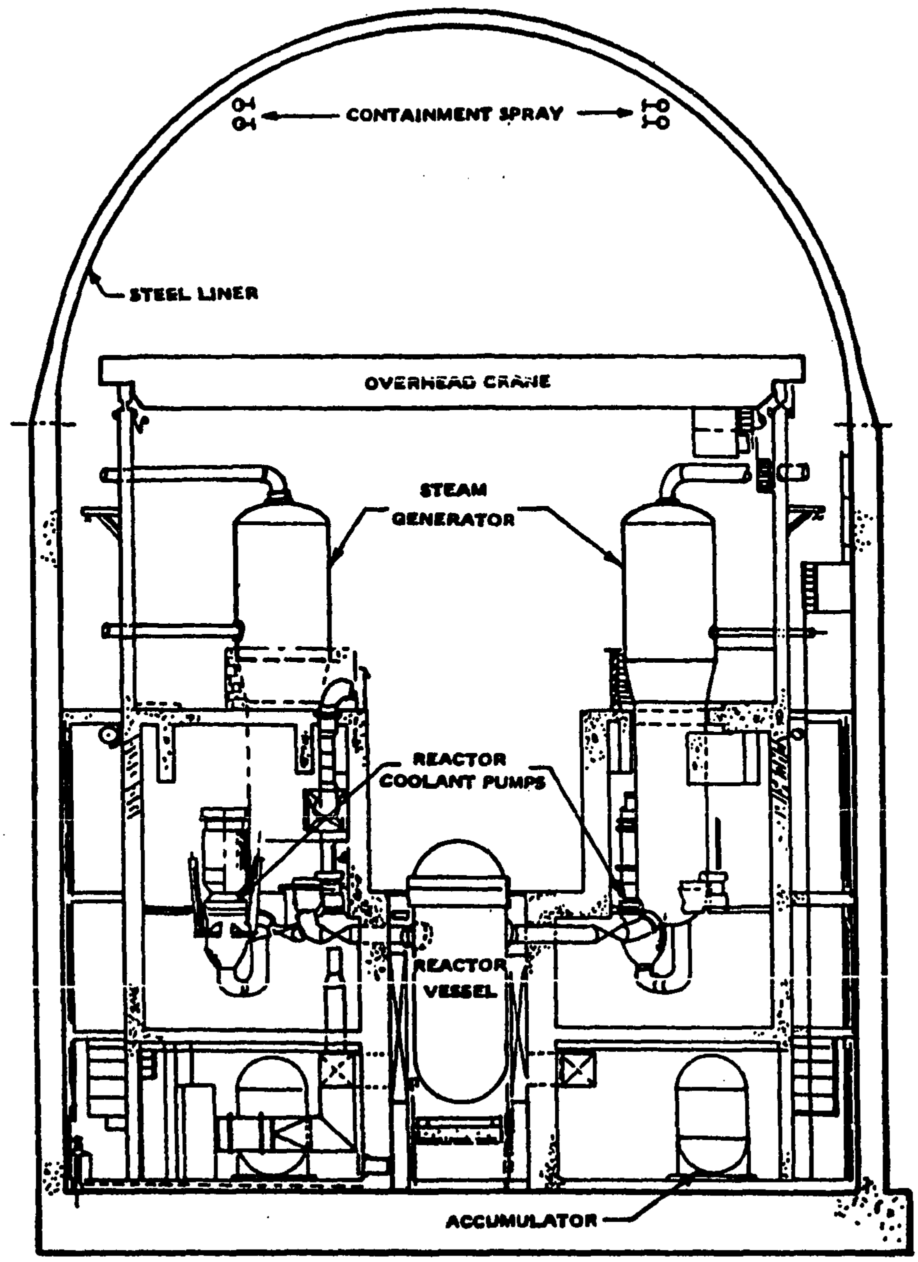


Figure 4.2. Typical PWR containment (46)

In ice condenser containment, the cooling duties of the emergency containment air recirculation system are taken over by the ice bank. The ice is borated ice and functions both as a neutron poison and an iodine scavenger. Because of the ice cooling capacity, it limits the peak accident pressure in the structure and hence the emergency power requirements after an accident are reduced in the order of 70-80% (47).

4.3. The Nature of Nuclear Power Plant Accidents

NPP accidents can potentially release significant amounts of radioactivity to the environment. All the places in which fuel is located in a NPP and the amount of radioactivity in each location are identifiable. The largest amount of radioactivity resides in the reactor core, as is shown in Table 4.1. A smaller, but still large amount of radioactivity, is located in the spent fuel storage pool at the time refueling of the reactor is completed. In both these locations, the fuel is subjected to heating due to absorption of energy from the decay of radioactive materials.

Overheating of fuel occurs only if the heat being generated in the fuel exceeds the rate at which it is being removed. This type of heat imbalance in the fuel in the reactor core can occur only in the following ways:

(1) The occurrence of a loss of coolant event will allow the fuel to overheat unless emergency cooling water is supplied to the core. This item

Table 4.1. Typical radioactivity inventory for a 1000 MWe nuclear power reactor (1)

Location	Total inventory (curies) Fuel	Gap	Total	Fraction of core inventory Fuel	Gap	Total
Core[a]	8.0×10^{9}	1.4×10^{8}	8.1×10^{9}	9.8×10^{-1}	1.8×10^{-2}	1
Spent fuel storage pool (max.)[b]	1.3×10^{9}	1.3×10^{7}	1.3×10^{9}	1.6×10^{-1}	1.6×10^{-3}	1.6×10^{-1}
Spent fuel storage pool (avg.)[c]	3.6×10^{8}	3.8×10^{6}	3.6×10^{8}	4.5×10^{-2}	4.8×10^{-4}	4.5×10^{-2}
Shipping cask[d]	2.2×10^{7}	3.1×10^{5}	2.2×10^{7}	2.7×10^{-3}	3.8×10^{-5}	2.7×10^{-3}
Refueling[e]	2.2×10^{7}	2×10^{5}	2.2×10^{7}	2.7×10^{-3}	2.5×10^{-5}	2.7×10^{-3}
Waste gas storage tank	--	--	9.3×10^{4}	--	--	1.2×10^{-5}
Liquid waste storage tank	--	--	9.5×10^{1}	--	--	1.2×10^{-8}

[a]Core inventory based on activity 1/2 hour after shutdown.

[b]Inventory of 2/3 core loading; 1/3 core with three-day decay and 1/3 core with 150 day decay.

[c]Inventory of 1/2 core loading; 1/6 core with 150 day decay and 1/3 core with 60 day decay.

[d]Inventory based on 7 PWR or 17 BWR fuel assemblies with 150 day decay.

[e]Inventory for one fuel assembly with three day decay.

identifies a class of accidents, called loss of coolant accidents (LOCAs), in which a rupture in the reactor coolant system (RCS) would lead to loss of normal coolant.

(2) Overheating of fuel can result from transient events that cause the reactor power to increase beyond the heat removal capacity of the reactor cooling system. This item identifies a class of events called transients. A nuclear plant includes various electrical safety circuits and a system for rapid termination of the fission process to attempt to protect against damaging transients.

4.3.1. Loss of coolant accidents

A LOCA would result whenever the RCS experiences a break or opening large enough so that the coolant inventory in the system could not be maintained by the normally operating make-up system. NPP include many engineered safety features (ESFs) that are provided to mitigate the consequences of such an event. If the ESFs were to operate as designed, the reactor core would be adequately cooled and only small consequences would result. However, the potential consequences could be much larger if ESF failures were to result in overheating of the reactor core.

There are a number of ways in which a LOCA may be initiated. The most significant LOCA initiating events in the reactor safety study would be the following (45):

(a) Large pipe breaks (6 inches to approximately 3 feet equivalent diameter) which is defined as a large LOCA.

(b) Small to intermediate pipe breaks (2 inches to 6 inches equivalent diameter) which is defined as a small LOCA (S_1).

(c) Small pipe breaks (0.5 inches to 2 inches equivalent diameter) which is defined as a small LOCA (S_2).

The course of events following a LOCA initiating event is strongly influenced by the degree of successful operation of the various ESFs. The ESF functions are illustrated in Fig. 4.3. The ways in which failures of these functions influence the outcome of LOCAs are discussed briefly below:

(a) The reactor trip (RT) function is to stop the fission process and terminate core power generation and is accomplished by rapid insertion of the reactor control rods. The action is initiated automatically by electrical signals generated if any of a number of key operating variables reaches a preset level.

(b) The emergency core cooling (ECC) function is to cool the core, thereby keeping the release of

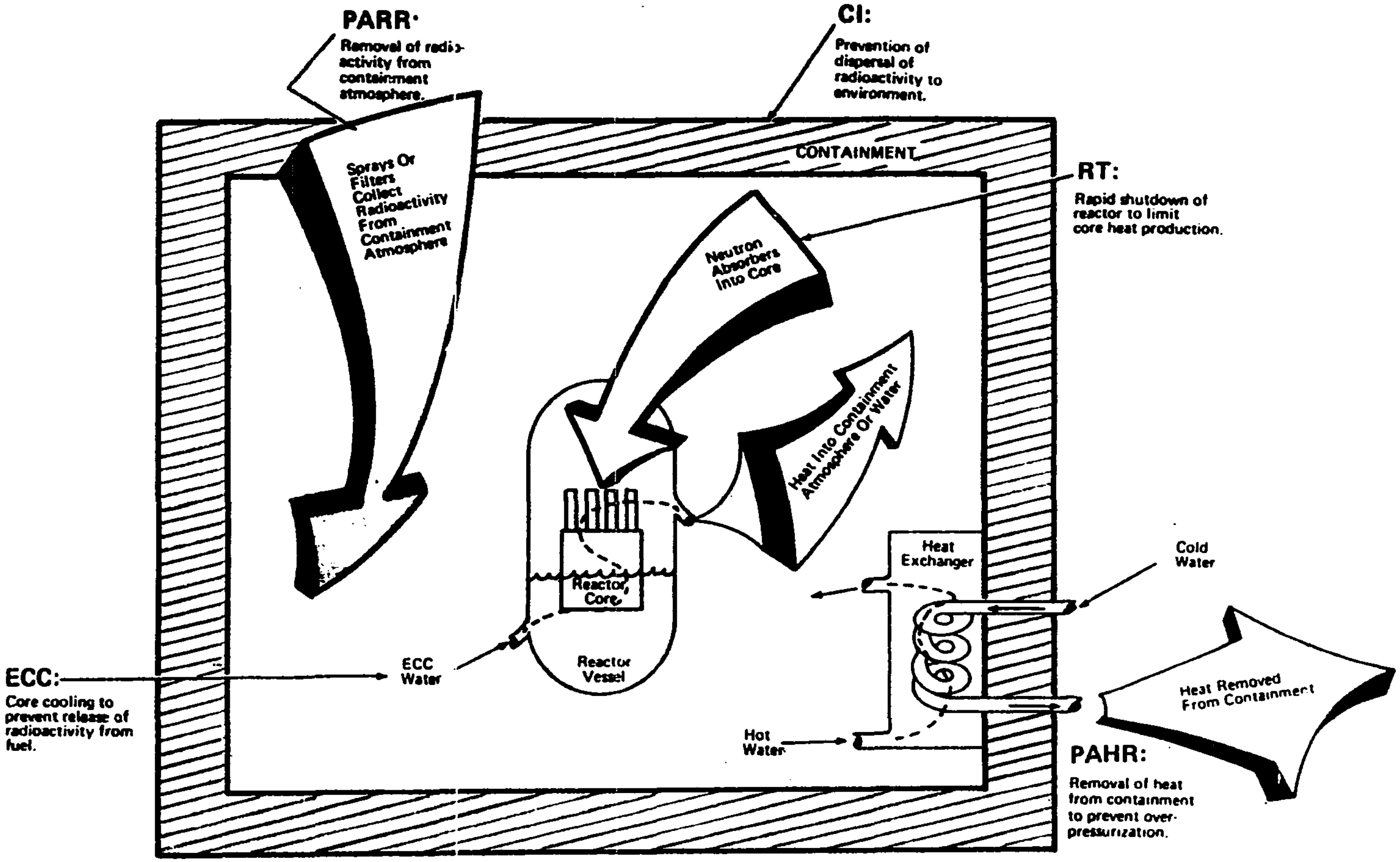


Figure 4.3. Functions of the engineered safety features (ESFs) of the light water reactors (LWRs)

radioactivity from the fuel into the containment at low levels. ECC involves a number of systems that deliver a supply of emergency coolant to the reactor core. These systems are shown in Figs. 4.4 and 4.5. A PWR plant includes high pressure systems primarily for coping with small LOCAs and low pressure systems primarily for large LOCAs.

(c) The post accident radioactivity removal (PARR) function is to remove radioactivity released from the core to the containment. In a PWR, this function is performed by systems that spray water into the containment atmosphere. These systems are shown in Fig. 4.6. The water spray, which includes a chemical additive for increasing iodine removal, washes radioactivity out of the containment atmosphere.

(d) The post accident heat removal (PAHR) function is to remove decay heat from within the containment, thereby preventing overpressurization of the containment. PAHR is performed by systems that transfer heat from heated water within the containment to cold water outside the containment. These systems are shown in Fig. 4.7. In a PWR, the containment water that flows through the primary side of the heat exchanger is taken from the reactor

ECI

Borated water is furnished to cool the core by three systems:

1) accumulators,

2) the Low Pressure Injection System (LPIS), and

3) the High Pressure Injection System (HPIS).

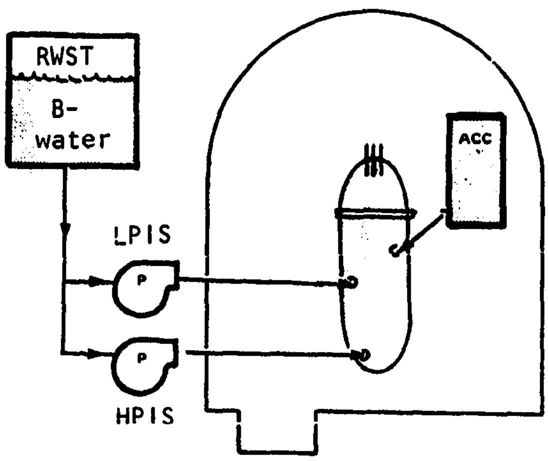


Figure 4.4. PWR emergency core cooling system (1)

ECR

The core is cooled by heat being transferred to containment by two systems:

1) the Low Pressure Recirculation System (LPRS), and

2) the High Pressure Recirculation System (HPRS). Both systems, using injection pumps aligned to a recirculation mode, pump water from a containment sump into the core.

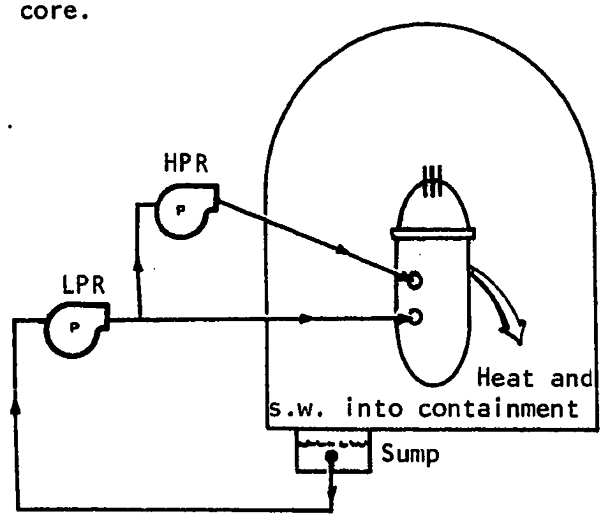


Figure 4.5. Emergency core recirculation systems (1)

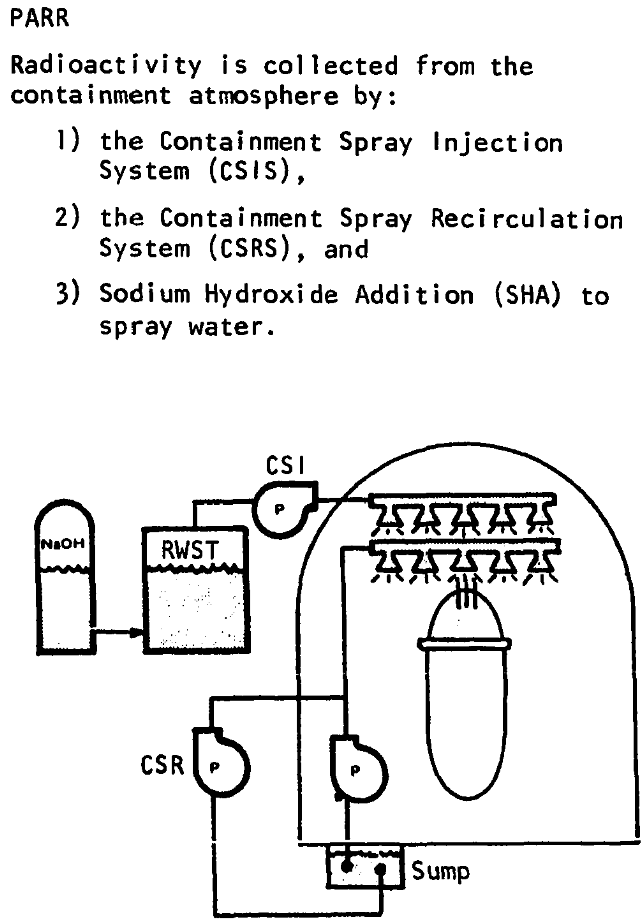


Figure 4.6. PWR post accident radioactivity removal system (1)

PAHR

Heat is removed from containment by heat exchangers that involve two systems:

1) the Containment Spray Recirculation System (CSRS), and
2) the Containment Heat Removal System (CHRS).

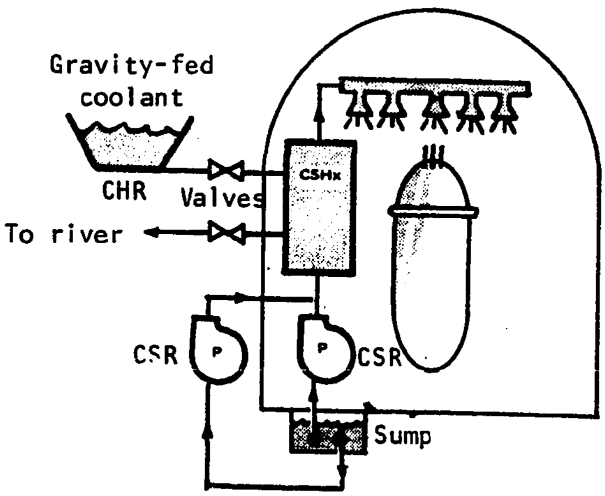


Figure 4.7. PWR post accident heat removal systems (1)

building sump. This is a particularly important function, since failure to perform this function can lead to overpressure failure of the containment and related failure of ECC systems.

(3) The containment integrity (CI) function is to prevent radioactivity within the containment from being dispersed into the environment.

4.4. Reactor Transients

The term reactor transient applies to any significant deviation from the normal operating value of any reactor operating parameter. Transient events can be assumed to include all those situations which could lead to fuel heat imbalances. When viewed in this way, transients cover the reactor in its shutdown condition as well as in its operating condition. The shutdown condition is important because many transient conditions result in shutdown of the reactor and decay heat removal systems are needed to prevent fuel-heat imbalance due to core decay heat.

Transients may occur as a consequence of an operator error or the malfunction or failure of equipment. Many transients are handled by the reactor control system, which would return the reactor to its normal condition. Others would be beyond the capability of the reactor control system and require reactor shutdown by the reactor protection system in order to avoid reactor damage.

In any safety analysis study, each potential transient is assessed to fall into either one of the two general categories, anticipated (likely) transients and unanticipated (unlikely) transients. Transients that have been found to be important to risk assessment are those that involve the loss of offsite power and loss of the plant heat removal systems.

5. S_2C ACCIDENT SEQUENCE AND ITS HUMAN CONTRIBUTION TO RISK IN NUCLEAR POWER PLANTS

5.1. Introduction

As mentioned in Section 1, a number of accident sequences that provide the highest contribution to risk have been analyzed. These accident sequences were selected for more in-depth analysis related to human contribution to risk. One of those accident sequences is S_2C, which is defined as a small LOCA and core meltdown after containment failure. A complete analysis and description of this sequence will be given in Section 5.2. Section 5.3 gives a complete description of those systems and subsystems which are found to have direct or indirect involvement in this accident sequence based on the analysis done in Section 5.2. Based on this analysis also, the human actions that can affect the initiation, progress and termination of the sequence will be identified.

5.2. S_2C Accident Sequence Description

This accident sequence is one of interest because it was found to make a significant contribution to the probability of a core melt and to potentially large releases of radioactive materials. This potential sequence is initiated by a small LOCA (S_2). During the course of the sequence, failure of the containment spray injection system (CSIS) can occur. Because of an identified dependency, failure of CSIS could result in the failure of both the containment spray recirculation system (CSRS) and the containment heat removal system (CHRS).

This could cause the containment to fail in an overpressure mode after several hours. During this interval, the emergency core cooling injection (ECIS) and recirculation (ECRS) systems are assumed to have been successfully operating to cool the core. On containment failure (at a pressure of approximately 100 psia), the coolant residing in the containment, which is at an elevated temperature, would flash and cause the ECRS pumps to cavitate and fail. The core could then melt in a containment that has already failed.

Investigation of potential system-to-system dependencies arising from various small-LOCA locations revealed that if the small LOCA (S_2) occurred, for example, in the region of the reactor vessel cavity, there would not be adequate pathway for the spilled coolant to flow between the cavity region and the containment "sump" used by the CSRS. Since the CSRS pumps would be automatically actuated after the LOCA occurrences, they could fail shortly after they were started if the supply of water in the sump was inadequate. Thus, it appears that successful operation of the CSRS could occur only if the CSIS were to operate and thus provide a supply of water to the sump. The following important points should be drawn from the previous description:

(a) A failure of the CSIS prevents the addition of large quantities of borated water to the containment. Since only a small portion of the reactor coolant system inventory leaks to the sump, sufficient elevation head is not available and LPRS pump cavitation will occur.

(b) Failure of the CSIS and the CSRS prevents spray operation, eliminating the need for the SHAS.

(c) Failure of the CSRS prevents delivery of sump water to the CHRS head exchange; therefore, operation of the CHRS has no effect.

According to this analysis, the following systems and subsystems were found to have direct or indirect involvement in this accident sequence:

(a) Containment spray injection system (CSIS).

(b) Containment spray recirculation system (CSRS).

(c) Containment heat removal system (CHRS).

(d) Sodium hydroxide addition system (SHAS).

5.3. S_2C Accident Sequence Systems Description

5.3.1. CSIS description and function

The CSIS delivers cold water containing boron through spray heads to the containment volume from the refueling water storage tank (RWST) during a loss of coolant accident

(LOCA). The principal function of the CSIS is to reduce the pressure in containment and also to provide the preferred path for delivery of sodium hydroxide to the containment atmosphere for initial fission product removal.

The CSIS consists of two essentially identical spray subsystems each capable of delivering 3200 GPM of water from the RWST to the containment atmosphere through 360° spray headers. Each spray header has 368 equally spaced nozzles located in the containment. Both subsystems take suction from a weir in the 350,000 gallon RWST. The weir is provided so that the sodium hydroxide solution delivered to the RWST can be preferentially extracted by the CSIS.

Fig. 5.1 is a simplified flow diagram of the CSIS. The valve positions shown in Fig. 5.1 are those for normal plant operation. In order to operate both subsystems of the CSIS, valves V_5 and V_6 and V_7 or V_8 must be opened and pumps P_1 and P_2 must be started. In the event of a LOCA, this would normally be done by a signal from the consequence limiting control system (CLCS). It should be noted that valves V_1 and V_3 also receive a CLCS signal to prevent those valves from being closed during the CSIS operation or to open them should they have been inadvertently closed.

The CSIS is designed on the following basis:

(a) Either spray subsystems S1 or S2 will provide sufficient spray to the containment atmosphere.

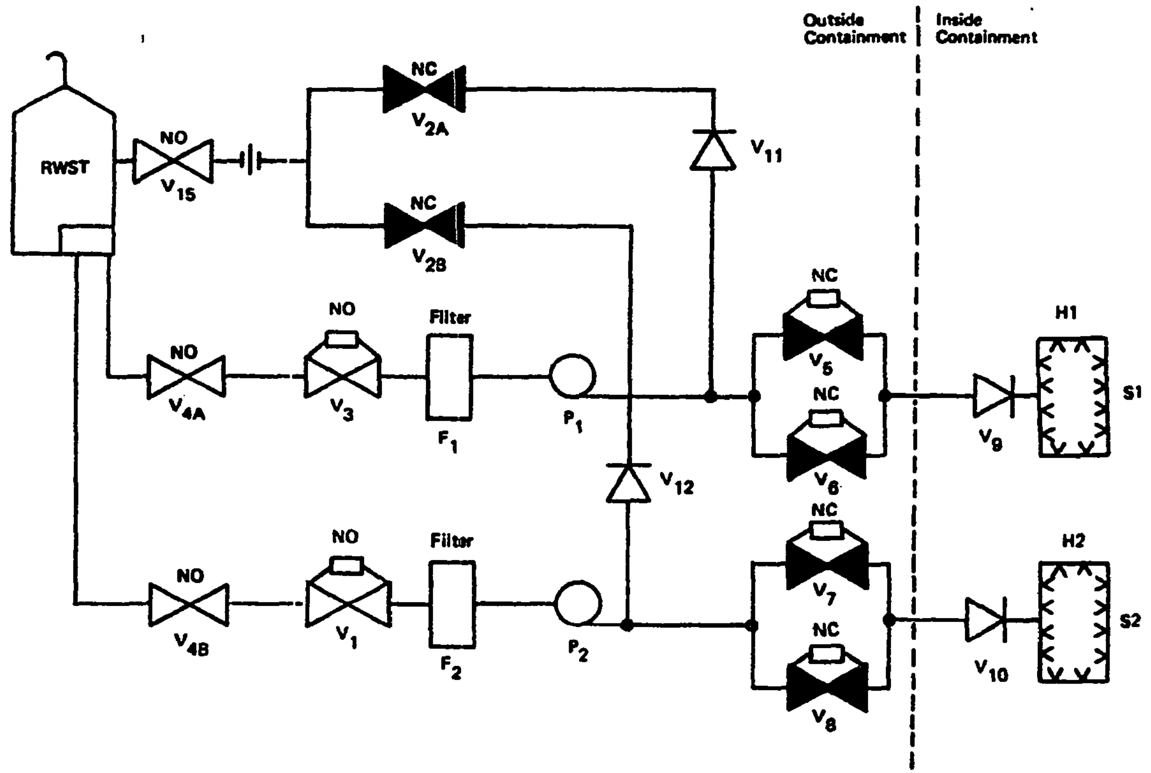


Figure 5.1. CSIS simplified flow diagram

(b) The CSIS is required to function only until the water supply in the RWST is exhausted.

Because the failure mode important to this analysis is a common mode failure, a brief discussion will be presented on this subject. Several different common mode possibilities were investigated. It was estimated that the largest contributions would arise from two faults, both of which result from human errors. The first fault is a common mode failure of the CLCS due to miscalibration of several sensors that in effect prevent the proper CLCS signal from reaching the CSIS in the event of LOCA. The second common mode failure analyzed was the possibility that both the CSIS pump flow recirculation valves V_{2A} and V_{2B} were left open after the monthly pump test due to operator error. Another possible fault is leaving manual valves V_{4A} and V_{4B} closed after maintenance.

5.3.2. CSRS description and function

The CSRS provides coolant for recirculation of the containment pump water through the heat exchangers of the CHRS to spray headers inside containment for the purpose of pressure control, fission product removal, and long-term energy removal in the event of a LOCA.

Fig. 5.2 is a simplified flow diagram of the CSRS and as can be seen from this figure, all stop valves in the flow path from the containment sump to the nozzle headers are

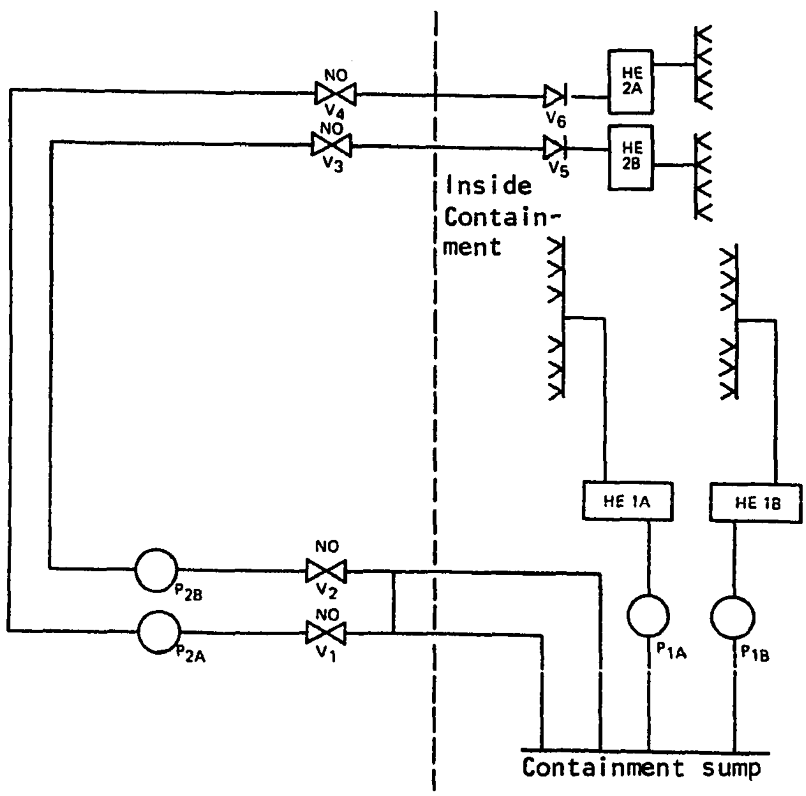


Figure 5.2. CSRS simplified flow diagram (1)

normally open. Thus, water can be delivered from the containment sump to the nozzles by turning on pumps P_{1A}, P_{1B}, P_{2A}, P_{2B}.

The following are some of the design features of the CSRS system:

(1) All four pump subsystems obtain their suction water from the containment sump.

(2) One inside pump and one outside pump receive their electrical power from the same emergency bus while the other pair of pump motors receive their power from another emergency bus.

(3) The CSRS is initially aligned for recirculation through all four headers.

5.3.3. <u>CHRS description and function</u>

The CHRS function is to cool containment sump water being recirculated through the CSRS. The CSRS is automatically started following a LOCA and in conjunction with CHRS provides heat removal from the containment.

Fig. 5.3 is a simplified flow diagram of the CHRS. The CHRS is designed on the following basis:

(1) Two of the four heat exchangers are required for the first 24 hours following an accident, and only one heat exchanger is required after that period.

(2) Sufficient cooling water flow to all four heat exchangers can be obtained through either of two

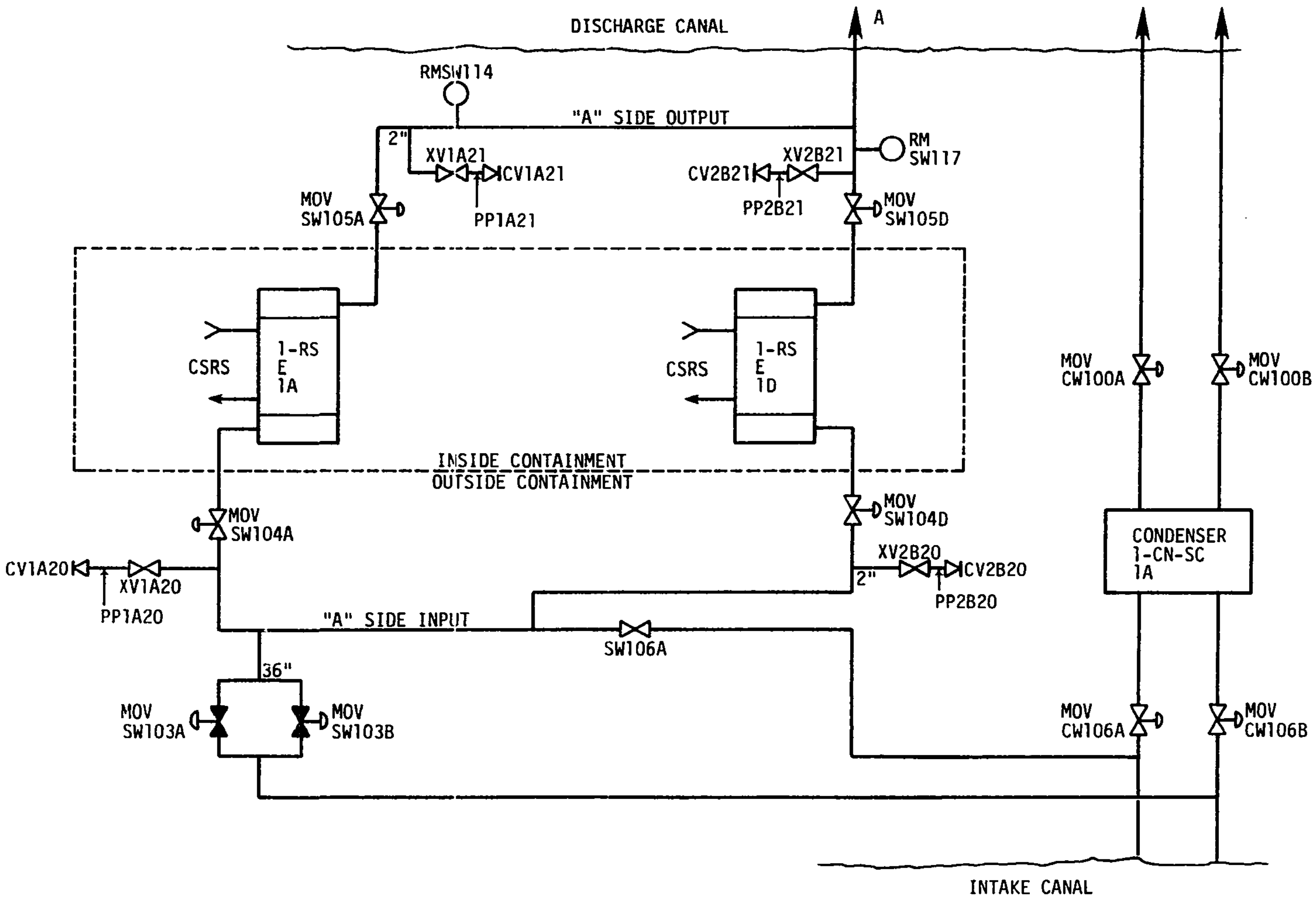


Figure 5.3. CHRS simplified flow diagram (1)

lines from the intake canal and through any one of the four MOV-SW-103 valves provided that normally open valves MOV-SW-106A and SW-106B are open.

(3) The air vents have manual valves which are normally open.

(4) The loss of off-site power results in each of the four condenser lines on unit 2 having only one valve each with power available for closing the valve.

5.3.4. <u>SHAS description and function</u>

Sodium hydroxide is automatically added to the refueling water storage tank (RWST) by the SHAS. When an accident causes pressure conditions in the containment to exceed a preset level, the SHAS provides an active solution for radioactivity removal by the CSIS and CSRS.

Fig. 5.4 is a simplified SHAS flow diagram, and it is designed on the following basis:

(1) Manual stop valves V_1, V_2, V_5, and V_6 are normally open.

(2) Motor operated stop valves V_3 and V_4 are normally closed.

(3) V_3 and V_4 are opened automatically by the Consequence Limiting Control System (CLCS) issuing an electrical signal to the control circuits of the

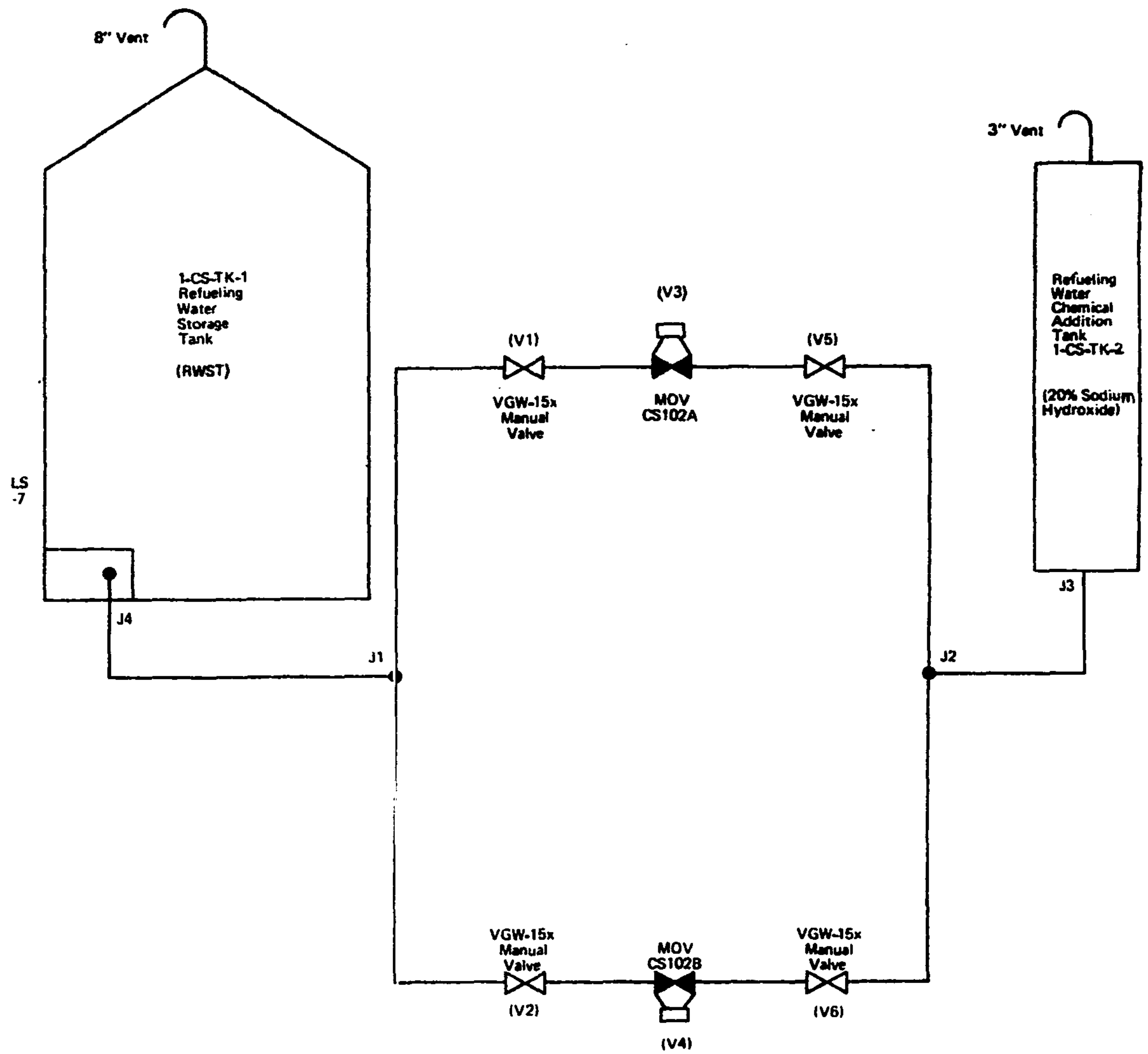


Figure 5.4. SHAS simplified flow diagram (1)

two valves when the LOCA occurs.

(4) When LOCA occurs, the NaOH solution of 20% concentration contained in the 3670 gallon chemical addition tank is free to flow into the 350,000 gallon RWST under the influence of a gravity driving head until the water level becomes the same in both tanks and therefore NaOH solution is added to the RWST.

6. ESTIMATION OF UNAVAILABILITY OF THOSE SYSTEMS INVOLVED IN S_2C ACCIDENT SEQUENCE

6.1. Introduction

To date there has been no systematic program to collect human error probabilities (HEPs) or human error rates in operating NPPs. The only formal record of errors in NPPs are the Licensee Event Reports (LERs), which can be used to derive HEP.

Since those systems and subsystems described in Section 5 have important involvement in the S_2C sequence, the contribution of human errors to their unavailabilities will be calculated and presented in Section 6.2.3. The calculation of these unavailabilities is done by utilizing the method described in Section 6.2.2 and the results will be compared with those found in WASH-1400. Discussion and comparison of the results are presented in Section 6.2.4.

6.2. Method of Calculation

6.2.1. Distribution of human performance

All human performance displays variability within the same individual and among individuals. Generally, intra-individual variability is small compared with the variability among different persons. Moreover, it is difficult to predict in advance an individual's variability. Here the concern is with inter-individual variability, i.e., the variability among properly trained and experienced operating personnel.

Despite variability among people, managerial influences in most technical jobs tend tc restrict variability under normal operating conditions. If a person consistently performs far below the average for his group, he usually will be reassigned, retrained for the job in question, or terminated (48). If he performs consistently, he usually will be promoted or transferred to a more challenging and responsible position.

When statistical data are collected from experiments of human performance, different probability distributions occur. Normal, lognormal, Weibull, Gamma, exponential, or other distribution may, depending on the data, closely fit the empirical distributions (48).

Most human traits and abilities do not conform to the Gaussian (normal) distribution. The only human distributions which are truly normal are those which pertain to the linear measurements of people, such as stature, lengths of extremities, the various diameters of the skull, and certain of their ratios like the cephalic index (49).

It is recognized that the distribution of the logarithms of HEPs for NPP tasks is often normal or approximately so. This could be stated in another way; the HEPs are lognormally distributed (50).

There are a number of studies that support the use of a lognormal distribution for performance of skilled people. In one study (51), an analysis of human performance data revealed lognormal type distributions for simple tasks and slightly skewed distributions approaching the normal for more complicated tasks. The parameters of the applicable lognormal distribution are speculative. Fig. 6.1 shows that for most NPP tasks, a lognormal probability density function (pdf) with a standard deviation of 0.42 would provide a suitable fit. The experimental measurements are also given (51).

Although one would like to have data clearly showing the distributions of human performance for various NPP tasks, there is ample evidence that the outcome of human reliability analyses are relatively insensitive to assumptions about such distributions (52). In some cases, this insensitivity may result from a well-designed system which has so many recovery factors that the effect of any one human error on the system is not substantial. For computational convenience, one might wish to assume the same distribution curve for human failure as the one used for equipment failure.

6.2.2. Availability theory

Availability may be defined as the time fraction during which a component or a system is operational. The availability allows for failure; that is, it accounts for loss of

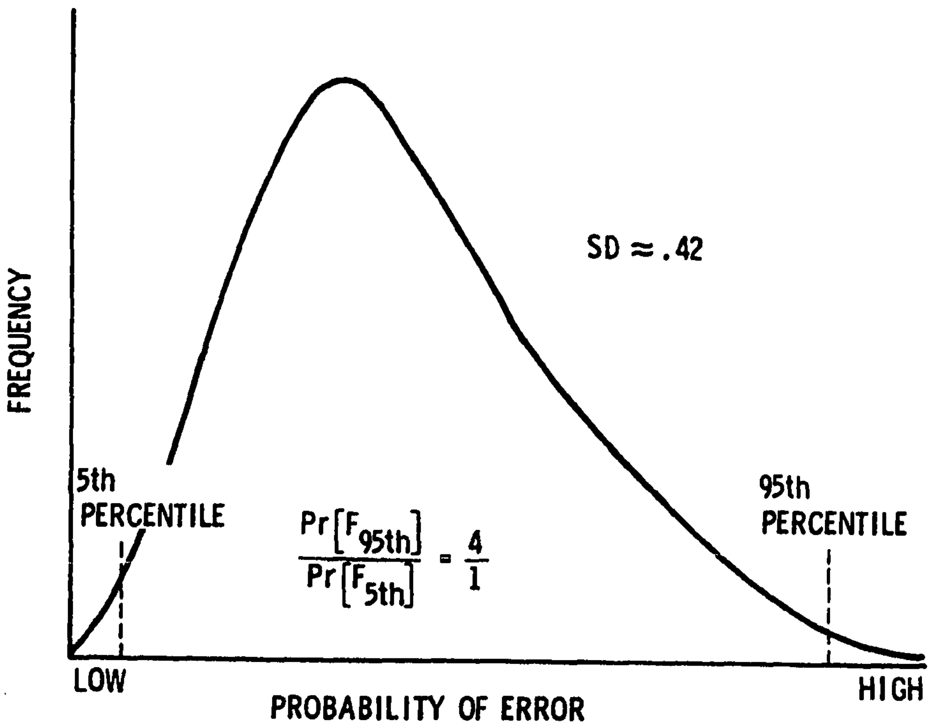


Figure 6.1. Hypothesized lognormal probability density function for NPP personnel (51)

function completely and for subsequent repairs. In contrast to reliability, availability does not depend on time as a parameter since long-term availability is a time invariant. The availability, $\hat{Q}$, can be estimated using the formula

$$\hat{Q} = \frac{\text{uptime}}{\text{uptime + downtime}} = \frac{T_a}{T_a + T_d} \ . \tag{6.1}$$

If n failures occur in a total time T, then the total "down" time or "dead" time, T_d, associated with a total time, T, is

$$T_d = n\ \tau_r \tag{6.2}$$

where τ_r is a fixed time duration which represents the repair time or its equivalent. The total time in which the component is available or the "up" time, T_a, is

$$T_a = T - n\tau_r \ . \tag{6.3}$$

Substituting equations 6.2 and 6.3 into equation 6.1 yields

$$\hat{Q} = \frac{T - n\tau_r}{T} \ . \tag{6.4}$$

For the limiting case ($T\to\infty$), the availability is

$$\hat{Q} = \lim_{T\to\infty} \frac{T-n\tau_r}{T} \tag{6.5}$$

$$= 1 - \lim_{T\to\infty} \frac{n\tau_r}{T} \ . \tag{6.6}$$

The second term on the right side is the "fractional dead time" or "unavailability", q; that is,

$$q = \lim_{T\to\infty} \frac{n\tau_r}{T} \qquad (6.7)$$

or without the limiting case, the unavailability is

$$q = \frac{n\tau_r}{T} \quad . \qquad (6.8)$$

When failure occurs by chance, the number of failures n may be written as

$$n = \lambda T_a \qquad (6.9)$$

where λ is the failure rate (failure/hour) for a component or a system.

Since T_a is the actual test or operation time, combining equations 6.3 and 6.9 gives

$$n = \frac{\lambda T}{1 + \lambda\tau_r} \quad . \qquad (6.10)$$

Substituting this quantity into equations 6.6 and 6.8 yields

$$Q = \frac{1}{1 + \lambda\tau_r} \qquad (6.11)$$

and

$$q = \frac{\lambda\tau_r}{1 + \lambda\tau_r} \quad . \qquad (6.12)$$

When $\lambda\tau_r << 1$ equations 6.11 and 6.12 may be written as

$$Q = 1 - \lambda\tau_r \qquad (6.13)$$

and

$$q = \lambda\tau_r \quad . \qquad (6.14)$$

The results given in equation 6.13 could be derived by using the general expression for the reliability which is given by

$$Q = \frac{1}{T} \int_0^T R(t)\ dt \qquad (6.15)$$

where R(t) is the reliability of the system or the component.

The results given in equation 6.14 could be used to calculate the unavailability of a system or a component by knowing its failure rate (λ) and repair time (τ).

Using equation 6.1, the unavailability can be written as

$$\underline{\hat{q}} = 1 - \frac{T_a}{T_a + T_d} = \frac{T_d}{T_a + T_d} \qquad (6.16)$$

This expression for unavailability is appropriate where the probability of being in a failed state is independent of time.

To evaluate the human error contribution to component or system unavailability, the same unavailability equations that are used in reliability theory for component and system failure occurrences can be used (human error simply being a particulare cause of failure).

Consider a human action that is performed periodically with an average time, $\bar{T}$, occurring between actions. Assume that on any action there is a probability, P, that a human error will occur and not be corrected. Also, assume that the average downtime given an error is T_d. Then, using equation 6.16, we have

$$\underline{\hat{q}} = \frac{PT_d}{\bar{T}} \quad . \tag{6.17}$$

To calculate the unavailability $\underline{\hat{q}}$ from equation 6.17, we need P, T_d, and $\bar{T}$. The probability, P, is obtained from any available sources of human error probabilities. The quantities, T_d and $\bar{T}$, are obtained from knowledge of plant operation.

6.2.3. Unavailability estimations

As stated previously, in order to calculate the unavailability of various components and systems of NPP due to the human, error rates must be calculated.

One needs to define the different types of error rates which can be calculated, specifically the error rate per hour (λ_h) and error rate per act (λ_a). The error rate per hour λ_h is estimated by taking the ratio of the number of errors F divided by the population exposure time T

$$\hat{\lambda}_h = \frac{F}{T} \tag{6.18}$$

where

$\hat{\lambda}_h$ = the error rate,

F = the number of errors observed in the LERs during the time t, and

$$T = Pct \tag{6.19}$$

where

P = number of nuclear power plants (covered by LERs),

c = number of components in a given system which is under consideration, and

t = LER time period.

If the system under consideration has different numbers of components that are susceptible to the error or if the LER observation times on the plants are different, then equation 6.19 would be replaced by the more general equation

$$T = \sum_{K+1}^{P} C_k t_k \tag{6.20}$$

where

C_k = number of components in the system in plant k and

t_k = observed time for plant k.

If one wanted the component error rate regardless of the system, then T = PCt. Here C is the number of components in the plant regardless of the system.

In general, for a component error rate, equation 6.19 will be used to calculate T and the number of errors F in the components will be counted. In addition to component error rates, one also has to define system error rates and plant error rates. For the system error rates, we have

F = number of applicable errors in the system (i.e., on any component in the system), and

$$T = Pt \ . \tag{6.21}$$

If there is more than one system of the given type in the plant, then

$$T = MPt \tag{6.22}$$

M = number of systems per plant.

For the plant error rate per hour, we have the same T as given by equation 6.21, but now

F = number of applicable errors on any system in the plant.

In general, error rates may be ranked with regard to usefulness as follows: (a) component error rates are the most useful for safety analysis, (b) then system error rates, and (c) finally plant error rates which generally are so gross as to be of limited use.

The 90% confidence bounds on λ_h are (53):

$$\hat{\lambda}_h \frac{\chi^2_{0.05,2F}}{2F} \leq \lambda_h \leq \hat{\lambda}_h \frac{\chi^2_{0.95,2(2F+1)}}{2F} \tag{6.23}$$

where F is the number of the reported errors.

The unavailability point estimate and 90% confidence can be computed using the following relationships:

$$\hat{q} = \hat{\lambda}\tau_r = 360\ \hat{\lambda} \text{ per demand} \qquad (6.24)$$

where

$\hat{\lambda}$ = failure (error) rate per hour and

τ_r = average repair time in hours

and the 90 percent confidence limits on q are (53):

$$\hat{q}\chi^2_{0.05,2F} \text{ per demand} < q < \hat{q}\ \chi^2_{0.95,2(F+1)} \text{ per demand.} \qquad (6.25)$$

Experience in reviewing the failure data shows that the average repair time (τ_r) is approximately two weeks.

There were a total of 529 reported operator events (Appendix A); 210 of these were from PWRs and 209 from BWRs (24). This study will analyze only those events reported from all PWR facilities. The data analyzed are from the period of January 1, 1976, through January 1, 1978. This accounted for 100.76 reactor years of operation. This section will present the calculation of the unavailabilities of those systems involved in the S_2C accident sequence described in Section 5.3. Tables 6.1 and 6.2 describe the operational errors analyzed based on information reported in the LERs for the CSIS, CSRS, CHRS and SHAS. The notation used is explained in Appendix A. From the above analysis, one can note the following:

(1) PWR reactor years surveyed = 100.76 years

(2) T = population exposure time in consideration

Table 6.1. Analyzed operator errors reported in the LERs for the CSIS and the CSRS

No.	System code	Component code	Failure mode code	ID No.
1	SB (CSIS)	VX	2AL	15
2	SA (CSIS)	VO	2CL	21
3	SB (CSIS)	VO	2CL	39
4	SF (CSIS)	VO	1VF	43
5	SB (CSIS)	VO	1VF	45
6	SB (CSIS)	VM	1CL	62
7	SB (CSIS)	OO	5MD	71
8	SB (CSIS)	VM	2OP	154
9	SA (CSIS)	PM	1FB	245
10	SB (CSIS)	VM	1OP	264
11	SB (CSIS)	CB	1VF	40
12	SF (CSIS)	CB	1VF	44
13	SB (CSIS)	CB	3FP	57
14	SH (CSIS)	CB	4CM	66
15	SH (CSIS)	OO	1RV	67
16	SB (CSIS)	OO	1CH	72
17	SB (CSIS)	CB	OP	171
18	SB (CSIS)	OO	1FB	182
19	SC (CSRS)	VX	1CL	243

Table 6.2. Analyzed operator errors reported in the LERs for the CHRS and the SHAS

No.	System code	Component code	Failure mode code	ID No.
1	SA (SHAS)	VX	1CL	31
2	SF (SHAS)	VM	1CL	132
3	SF (SHAS)	VO	4CM	65
4	SB (CHRS)	TX	5MD	520
5	SH (CHRS)	PM	4CM	66
6	SH (CHRS)	XX	4CM	67
7	SB (CHRS)	VO	1OP	333
8	SB (CHRS)	VM	3CL	339

$= 100.76$ years

$= 100.76 \text{ years} \times 8760 \frac{\text{hrs}}{\text{yrs}} = 8.827 \times 10^5$ hrs.

6.2.3.1. <u>CSIS unavailability estimation</u> Using Table 6.1,

F = # of human errors in this period of time = 18

N = # of CSIS = 1.

Using equation 6.18, the human error rate which led to unavailability of the CSIS is

$$\hat{\lambda}_h = \frac{F}{T} = \frac{18}{8.827 \times 10^5 \times 1} = 2.0 \times 10^{-5} \text{ hr}^{-1} .$$

Using equation 6.23, the 90% confidence bounds on λ_h are

$$1.04 \times 10^{-5} \text{ per hour} \leq \lambda_h \leq 2.49 \times 10^{-5} \text{ per hour.}$$

Using equation 6.24, the CSIS point estimate unavailability is

$$\hat{q} = 360 \, \hat{\lambda}_h = 7.34 \times 10^{-3} \text{ per demand}$$

and 90% confidence bounds on q are

$$3.75 \times 10^{-3} \text{ per demand} \leq \underline{q} \leq 8.96 \times 10^{-3} \text{ per demand.}$$

6.2.3.2. <u>CSRS unavailability</u> Using Table 6.1,

F = # of human errors in this period of time = 1

N = # of CSRS = 1.

Using equation 6.18, the human error rate which led to unavailability of the CSRS is

$$\hat{\lambda}_h = \frac{F}{T} = \frac{1}{8.827 \times 10^5 \times 1} = 1.13 \times 10^{-6} \text{ hr}^{-1}$$

Using equation 6.23, the 90% confidence bounds on λ_h are

$$4.0 \times 10^{-7} \le \lambda_h \le 3.4 \times 10^{-6} \text{ per hour .}$$

Using equation 6.24, the CSRS point estimate unavailability is

$$\hat{\underline{q}} = 360\ \hat{\lambda}_h = 4.08 \times 10^{-4} \quad \text{per demand}$$

and 90% confidence bound on $\underline{q}$ are

$$1.45 \times 10^{-4} \text{ per demand} \le \underline{q} \le 1.22 \times 10^{-3} \text{ per demand.}$$

6.2.3.3. <u>CHRS unavailability</u> Using Table 6.2,

F = # of human errors in this period of time = 5

N = # of CHRS = 1.

Using equation 6.18, the human error rate which led to unavailability of the CHRS is

$$\hat{\lambda}_h = \frac{F}{T} = \frac{5}{8.827 \times 10^5 \times 1} = 5.66 \times 10^{-6}\ \text{hr}^{-1} \quad .$$

Using equation 6.23, the 90% confidence bounds on λ_h are

$$2.96 \times 10^{-6} \le \lambda_h \le 1.04 \times 10^{-5} \text{ per hour} \quad .$$

Using equation 6.24, the CHRS point estimate unavailability is

$$\hat{\underline{q}} = 360\ \hat{\lambda}_h = 2.04 \times 10^{-3} \text{ per demand}$$

and 90% confidence bounds on $\underline{q}$ are

$$1.07 \times 10^{-3} \text{ per demand} \le \underline{q} \le 3.73 \times 10^{-3} \text{ per demand.}$$

6.2.3.4. SHAS unavailability Using Table 6.2,

F = # of human errors in this period of time = 3

N = # of SHAS = 1.

Using equation 6.18, the human error rate which led to unavailability of the SHAS is

$$\hat{\lambda}_h = \frac{F}{T} = \frac{3}{8.827 \times 10^5 \times 1} = 3.4 \times 10^{-6} \text{ hr}^{-1} \quad .$$

Using equation 6.23, the 90% confidence bounds on λ_h are

$$1.55 \times 10^{-6} \text{ per hour} \leq \lambda_h \leq 7.13 \times 10^{-6} \text{ per hour.}$$

Using equation 6.24, the SHAS point estimate unavailability is

$$\hat{\underline{q}} = 360\ \hat{\lambda}_h = 1.22 \times 10^{-3} \text{ per demand}$$

and 90% confidence bounds on $\underline{q}$ are

$$5.58 \times 10^{-4} \text{ per demand} \leq \underline{q} \leq 2.57 \times 10^{-3} \text{ per demand.}$$

6.2.4. Discussion of the results

The LER records at all PWR facilities operating between the period of January 1, 1976, through January 1, 1978, were reviewed to extract human related data relevant to the failure of those systems described in Section 5.3. The extracted data were used to calculate failure rates and unavailabilities of the systems involved in the S_2C accident sequence. The unavailabilities are summarized in Table 6.3. The

Table 6.3. S_2C accident sequence systems unavailabilities

System	Unavailability (per demand)[a]			Unavailability (per demand)[b]		
	Upper	Median	Lower	Upper	Median	Lower
Containment spray injection	8.96×10^{-3}	7.34×10^{-3}	3.75×10^{-3}	7.8×10^{-3}	2.4×10^{-3}	1.0×10^{-3}
Containment spray recirculation	1.22×10^{-3}	4.08×10^{-4}	1.45×10^{-4}	9.0×10^{-4}	1.0×10^{-4}	2.5×10^{-5}
Containment heat removal	3.73×10^{-3}	2.04×10^{-3}	1.07×10^{-3}	3.0×10^{-4}	8.5×10^{-5}	3.0×10^{-5}
Sodium hydroxide addition	2.57×10^{-3}	1.23×10^{-3}	5.58×10^{-4}	1.1×10^{-2}	5.9×10^{-3}	3.6×10^{-3}

[a]Using LER data (Section 6.2.3 of this report).

[b]From WASH-1400, Appendix II, Table II 1-2.

results are compared with the values given in WASH-1400 (1), Appendix II, Table II 1-2. As can be seen by inspection of Table 6.3, the unavailability of the CHRS as estimated in WASH-1400 is lower than the values obtained by use of LER records. The unavailabilities of the CSIS, the CHRS, and the SHAS as estimated using LERs agree within a factor of 5 or less with those values obtained using WASH-1400.

7. OPERATOR ERROR RATES ESTIMATION

7.1. Introduction

As it was indicated in Section 6.1, there is no program to collect human error rates in NPPs. The only record of errors in NPPs is in the LERs, which may be used to compute human error rates. In this section, operator error rates are estimated based on LER data for failure modes involving valves in analyzed PWR's subsystems described and presented in Section 5.3. A comparison is made between estimates obtained here and the values used in WASH-1400 (1) and those predicted in NUREG/CR-1278 by Swain (11).

The reason for the selection of this particular component failure (valve) is that, as can be noticed from the analysis of collected data (24), the most frequent operator error mode involves valves (mispositioning, inadvertent actuation, misalignment, etc.). This is illustrated in Tables 7.1, 7.2, and 7.3.

Human performance shaping factors (PSF) are believed to affect the human error rate estimates. Human PSF were presented in Section 3. However, in this study the effects of PSF on error rate estimates will not be addressed.

7.2. Operator Error Rate Estimates

The operator error rates (hourly or per demand) may be calculated based on the frequency counts provided in

Table 7.1. Frequent operator failure modes (24)

Component	Failure mode	Percent of total component occurrences BWR	PWR	Total	Percent of total operator errors
Valve	Left in wrong position	41	41	41	13
	Misalignment	29	15	20	6
	Inadvertent actuation	12	9	10	3
	Improper operation	8	7	7	2
Monitor/ detector	Did not check/test	38	24	31	2
	Did not monitor	24	24	24	2
	Left in/out of service	14	10	12	1
Control rod/ control Rod drive/ Control rod group	Did not check/test	30	6	20	2
	Procedure	26	12	20	2
	Exceeds limits	0	26	15	1
	Improper sequence	9	6	8	1
Pump	Improper operation	21	48	41	3
	Did not start/stop	23	10	15	1
	Procedure	15	10	12	1
	Did not check/test	8	14	12	1
Switch	Left in wrong position	15	57	32	2
	Mispositioning	35	14	26	2
	Inadvertent actuation	25	7	18	1
Breaker	Inadvertent actuation	33	26	28	1
	Deenergization	17	26	24	1
	Did not check/test	33	11	16	1
Tank	Exceeds limits	50	30	33	2
	Did not monitor	25	15	17	1
Alarm	No response	75	67	70	1
Diesel generator	Did not check/test	25	60	44	1
	Disregarded	25	20	22	0
Bus	Deenergization	67	40	50	1
	Did not check/test	0	40	25	0

Table 7.2. Systems affected by operator "errors) (operator errors recorded from January 1972 through December 19, 1977) (24)

System/component involved	Number of events BWR (100 plant-year)	Number of events PWR (77 plant-year)	Total	Percent of total operation errors
Emergency Core Cooling Injection System (ECCIS)	37	74	111 (48 valves)	21
Waste Processing System (WPS)	34	35	69 (38 valves)	13
Instrumentation and Monitoring System (IMS)	34	27	61	12
Reactor Power Control System (RPCS)	23	32	55 (29 control rod drive)	11
Secondary Non-Nuclear Systems (SMS)	10	30	40	8
Reactor Protection System (NPS)	20	16	36	7
Auxiliary Electric Power System (ALPS)	15	19	34 7	
Main Reactor Coolant System (RCS)	10	20	30 6	
Auxiliary Systems for Normal Operation (ASNO)	4	23	27	5
Other Containment Systems (CS)	12	13	25	5
Containment Spray and Recirculation Systems (SCRC)	1	21	22	4
Emergency Cooling Recirculation System (ICRS)	11	0	11 (10 Torus)	2
Total (Systems)	211	310	521	100

Table 7.3. Components affected by operator "errors" (operator errors recorded from January 1972 through December 19, 1977) (24)

System/component involved	Number of events BWR (100 plant-year)	PWR (77 plant-year)	Total	Percent of total operator errors
Valve	59	104	163	31
Monitor/detector	21	21	42	8
Control rod/Control rod drive/Control rod group	23	17	40	8
Pump	13	21	34	7
Switch	20	14	34	7
Breaker	6	19	25	5
Tank	4	20	24	5
Alarm	4	6	10	2
Diesel generator	4	5	9	2
Bus	3	5	8	2
Total components	157	232	389	76

Appendix A.

As presented in Section 6, the human error rate is defined as (24):

$$\lambda_H \ (M,S,C) = \frac{\sum_i f_i}{\sum_i N_i T_i}, \qquad \text{hourly} \qquad (7.1)$$

$$\lambda_D \ (M,S,C) = \frac{\sum_i f_i}{\sum_i N_i D_i}, \qquad \text{demand} \qquad (7.2)$$

where

f_i = Number of events related to failure mode "M" with component "C" in system "S" in the ith plant.

N_i = Population of component "C" in the system "S" in the ith plant.

T_i = Critical hours of the ith plant during which "f_i" events occurred.

D_i = Total number of demands on system "S" in the ith plant.

For the 90% confidence bounds on λ_H,

$$L = \text{lower limit} = \frac{\chi^2_{0.5,2\sum_i f_i}}{2 \sum_i f_i} \cdot \lambda_H$$

$$U = \text{upper limit} = \frac{\chi^2_{0.95,[2\sum_i f_i+2]}}{2 \sum_i f_i} \cdot \lambda_H \qquad (7.3)$$

7.3. Valve Mispositioning of Those Systems and Subsystems Involved in S_2C Accident Sequence

Tables 7.4, 7.5 and 7.6 provide the frequency count of events involving mispositioning of valves in the CSIS, the CSRS, the SHAS and the CHRS. Tables 7.7 through 7.10 provide the valve population and the critical hour data for the above systems and subsystems.

7.3.1. Human error rates estimated for CSIS

7.3.1.1. CSIS valve mispositioning failure rate calculation Failure rates for valve mispositioning (clustering of all failure modes that lead to valves being mispositioned in the CSIS) may be calculated from the above tables (Tables 7.4 and 7.7). The critical hours are extracted from Appendix A. The hourly failure rate of valves due to operator error is given by (using equation 7.1),

$$\lambda_H(M,S,C) = \frac{\sum_i f_i}{\sum_i N_i T_i}$$

where

M = mispositioning

S = CSIS (code SA, SB)

C = valve (code VM, VP, VX)

$\sum_i f_i$ = number of events related to failure mode "M" = 8

$\sum_i N_i T_i$ = 1.008×10^7 hours

$$\lambda_H(M,S,C) = \frac{8}{1.008 \times 10^7} = 7.94 \times 10^{-7}\ \text{hr}^{-1}$$

Table 7.4. Frequency count of events involving mispositioning of valves in the CSIS and the CSRS

Failure mode code	Failure mode	Component code	ID.No.	Event count
2AL[a]	Misalignment	VX	15	1
2CL	Did not close/ left open	VO	21, 39	2
1VF	Did not verify	VO	43, 45	2
1CL	Did not close/ left open	VM	62	1
2OP	Did not open/ left closed	VM	154	1
1OP	Did not open/ left closed	VM	264	1
Total				8
1CL[b]	Did not close/ left open	VX	243	1

[a]For CSIS.

[b]For CSRS.

Table 7.5. Frequency count of events involving mispositioning of valves in SHAS

Failure mode code	Failure mode	Component code	ID. No.	Event count
1CL	Did not close/ left open	VX	31	1
1CL	Did not close/ left open	VM	132	1
4CM	Communication	VO	65	1
Total				3

Table 7.6. Frequency count of events involving mispositioning of valves in CHRS

Failure mode code	Failure mode	Component code	ID. No.	Event count
1OP	Did not open/ left closed	VO	333	1
3CL	Inadvertent closing	VM	339	1
Total				2

Table 7.7. Valve population, critical hours for all PWR plants for CSIS (period from January 1, 1972, to January 1, 1978)

Plant #	Critical hours (T_i)	Population of CSIS valves (N_i)	$T_i \times N_i$
1	40,000	11	4.401×10^5
2	22,010	11	2.421×10^5
3	8,982	11	9.88×10^4
4	27,368	11	3.01×10^5
5	37,695	11	4.146×10^5
6	14,748	11	1.622×10^5
7	25,023	11	2.753×10^5
8	22,413	11	2.465×10^5
9	2,845	11	3.130×10^4
10	9,266	11	1.019×10^5
11	33,411	11	3.675×10^5
12	26,682	11	2.935×10^5
13	23,909	11	2.63×10^5
14	10,950	11	1.205×10^5
15	34,388	11	3.783×10^5
16	21,377	11	2.351×10^5
17	33,922	11	3.731×10^5
18	43,604	11	4.796×10^5
19	41,703	11	4.587×10^5
20	28,795	11	3.167×10^5
21	29,534	11	3.249×10^5
22	18,138	11	1.995×10^5
23	41,864	11	4.605×10^5
24	26,516	11	2.917×10^5
25	27,557	11	3.031×10^5
26	24,167	11	2.658×10^5
27	6,353	11	6.988×10^4

Table 7.7. (Continued)

Plant #	Critical hours (T_i)	Population of CSIS valves (N_i)	T_i x N_i
28	20,988	11	2.309×10^5
29	6,065	11	6.672×10^4
30	1,729	11	1.902×10^4
31	19,473	11	2.142×10^5
32	6,448	11	7.093×10^4
33	42,928	11	4.722×10^5
34	24,012	11	2.641×10^5
35	545	11	5.995×10^3
36	28,896	11	3.179×10^5
37	37,182	11	4.09×10^5
38	44,756	11	4.923×10^5
Total	T_i x N_i = 1.008×10^7 hours		

To express λ_H as a human error probability (HEP, dimensionless) to be compared with those values predicted in NUREG/CR-1278 (11), λ_H is multiplied by the duration in hours. The duration time is defined as the time between event initiation and detection. Experience in reviewing human related events shows that this time has a wide variability. It ranges between one minute and one month in all systems considered. Based on a one week time interval,

$$HEP = 7.937\ 10^{-7}\ (hr^{-1}) \times 168\ (hr) = 1.333 \times 10^{-4}\ .$$

Using equation 6.3, the 90% confidence bound on λ_H is

$$4.659 \times 10^{-7} \leq \lambda_H \leq 1.305 \times 10^{-6}\ hr^{-1}\ .$$

Using equation 6.24, the point estimate unavailability is

$$\hat{\underline{q}} = 2.857 \times 10^{-4} \text{ per demand}$$

and the 90% confidence bounds on $\underline{q}$ are

$$1.677 \times 10^{-4} \leq \underline{q} \leq 4.698\ 4.698 \times 10^{-4} \text{ per demand.}$$

7.3.1.2. <u>Failure rate calculation of CSIS valve being left closed or open</u> The failure rate for valves left closed or open in the CSIS may be calculated using Tables 7.4 and 7.7. Using equation 7.1, the hourly failure rate of valves left closed due to operator error is given by

$$\lambda_H\ (M_1, S, C) = \frac{\sum_i f_i}{\sum_i N_i T_i}$$

where

M_1 = valve left closed

S = CSIS (code SA, SB)

C = valve (code VM)

using Tables 7.4 and 7.7

$$\sum_i f_i = 2$$

$$\sum_i N_i T_i = 1.008 \times 10^7 \text{ hours}$$

$$\lambda_H\ (M_1, S, C) = \frac{2}{1.008 \times 10^7} = 2.0 \times 10^{-7}\ \text{hr}^{-1}$$

$$(\text{HEP})_{M_1} = \lambda_H \times \text{duration time} = 3.33 \times 10^{-5}\ .$$

The 90% confidence bound on λ is

$$8.0 \times 10^{-8} \leq \lambda_H \leq 4.7 \times 10^{-7}\ \text{hr}^{-1}$$

and the 90% confidence bounds on $(\text{HEP})_{M_1}$ are

$$1.36 \times 10^{-5} \leq (\text{HEP})_{M_1} \leq 7.9 \times 10^{-5}\ .$$

Using equation 7.1, the hourly failure rate of valve left closed due to operator error is given by

$$\lambda_H (M_2, S, C) = \frac{\sum_i f_i}{\sum_i N_i T_i}$$

where

M_2 = valve left open

S = CSIS (code SA, SB)

C = valve (code VO, VM)

using Tables 7.4 and 7.7

$$\sum_i f_i = 3$$

$$\sum_i N_i T_i = 1.008 \times 10^{-7} \text{ hours}$$

$$\lambda_H(M_2,S,C) = \frac{3}{1.008 \times 10^7} = 3.0 \times 10^{-7} \text{ hr}^{-1}$$

$$(HEP)_{M_2} = \lambda_H \times \text{duration time} = 5 \times 10^{-5} .$$

The 90% confidence bounds on λ_H are

$$1.4 \times 10^{-7} \leq \lambda_H \leq 6.3 \times 10^{-7} \text{ hr}^{-1}$$

and the 90% confidence bounds on $(HEP)_{M_2}$ are

$$2.28 \times 10^{-5} \leq (HEP)_{M_2} \leq 1.05 \times 10^{-4} .$$

7.3.2. Human error rates estimated for CSRS

Failure rate for valve left closed (which is the only event reported by LERs) in the CSRS may be calculated by using Tables 7.4 and 7.8. The critical hours are extracted from Appendix A.

The hourly failure rate of valves due to operator error is given by

$$\lambda_H(M,S,C) = \frac{\sum_i f_i}{\sum_i N_i T_i}$$

Table 7.8. Valve population, critical hours for all PWRs plants, CSRS (period from January 1, 1972, to January 1, 1978)

Plant #	Critical hours (T_i)	Population of CSIS valves (N_i)	$T_i \times N_i$
1	40,000	7	2.8×10^5
2	22,010	7	1.54×10^5
3	8,982	7	6.287×10^4
4	27,368	7	1.916×10^5
5	37,695	7	2.639×10^5
6	14,748	7	1.032×10^5
7	25,032	7	1.752×10^5
8	22,413	7	1.569×10^5
9	2,845	7	1.992×10^4
10	9,266	7	6.486×10^4
11	33,411	7	2.339×10^5
12	26,682	7	1.868×10^5
13	23,909	7	1.674×10^5
14	10,950	7	7.665×10^4
15	34,388	7	2.407×10^5
16	21,377	7	1.496×10^5
17	33,922	7	2.375×10^5
18	43,604	7	3.052×10^5
19	41,703	7	2.919×10^5
20	28,795	7	2.016×10^5
21	29,534	7	2.067×10^5
22	18,138	7	1.270×10^5
23	41,864	7	2.93×10^5
24	26,516	7	1.856×10^5
25	27,557	7	1.929×10^5
26	24,167	7	1.692×10^5

Table 7.8. (Continued)

Plant #	Critical hours (T_i)	Population of CSIS valves (N_i)	$T_i \times N_i$
27	6,353	7	4.447×10^4
28	20,988	7	1.469×10^5
29	6,065	7	4.246×10^4
30	1,729	7	1.210×10^4
31	19,473	7	1.363×10^5
32	6,448	7	4.514×10^4
33	42,928	7	3.005×10^5
34	24,012	7	1.681×10^5
35	545	7	3.815×10^3
36	28,896	7	2.023×10^5
37	37,182	7	2.603×10^5
38	44,756	7	3.133×10^5
Total	$N_i \times T_i = 6.414 \times 10^6$ hours		

where

M = left closed

S = CSRS (Code SC)

C = valve (code VX)

$$\sum_i f_i = 1$$

$$\sum_i N_i T_i = 6.414 \times 10^6 \text{ hours}$$

$$\lambda_H (M,S,C) = \frac{1}{6.414 \times 10^6} = 1.5 \times 10^{-7} \text{ hr}^{-1}$$

and

$$HEP = 2.62 \times 10^{-4} \quad .$$

The 90% confidence bounds on λ_H are

$$5.5 \times 10^{-8} \leq \lambda_H \leq 4.7 \times 10^{-7} \text{ hr}^{-1} \quad .$$

Using equation 6.23, the point estimate unavailability $\underline{q}$ is

$$\hat{\underline{q}} = 5.61 \times 10^{-5} \quad \text{per demand}$$

and the 90% confidence bounds on $\underline{q}$ are

$$2.0 \times 10^{-5} \leq \underline{q} \leq 1.82 \times 10^{-4} \text{ per demand.}$$

7.3.3. Human error rates estimated for SHAS

7.3.3.1. SHAS valve mispositioning failure rate calculation The failure rate for valve mispositioning (clustering of all failure modes that lead to valves being mispositioned) in the SHAS may be calculated by using the information given in Tables 7.5 and 7.9. The critical hours are extracted from Appendix A.

The hourly failure rate of valves due to operator error is given by

$$\lambda_H\ (M,S,C) = \frac{\sum_i f_i}{\sum_i N_i T_i}$$

where

M = mispositioning

S = SHAS (code SH)

C = valve (code VX, VM, VO)

$$\sum_i f_i = 3$$

$$\sum_i N_i T_i = 5.279 \times 10^6 \text{ hours}$$

$$\lambda_H(M,S,C) = \frac{3}{5.279 \times 10^6} = 5.7 \times 10^{-7}\ hr^{-1}$$

$$HEP = 9.55 \times 10^{-5} \quad .$$

The 90% confidence bounds on λ_H are

$$2.6 \times 10^{-7} \le \lambda_H \le 1.2 \times 10^{-6}\ hr^{-1} \quad .$$

Using equation 6.24, the point estimate unavailability $\underline{q}$ is 2.05×10^{-4}. The 90% confidence bounds on $\underline{q}$ are

$$9.32 \times 10^{-5} \le \underline{q} \le 4.3 \times 10^{-4} \quad \text{per demand.}$$

7.3.3.2. Failure rate calculations of SHAS valve being left open The failure rate for a valve left open in the

Table 7.9. Valve population critical hours for all PWRs plants, SHAS (period from January 1, 1972, to January 1, 1978)

Plant #	Critical hours (T_i)	Population of SHAS valves (N_i)	$T_i \times N_i$
1	40,000	6	2.4×10^5
2	22,010	6	1.321×10^5
3	8,982	6	5.389×10^4
4	27,368	6	1.642×10^5
5	37,695	6	2.262×10^5
6	14,748	6	8.849×10^4
7	25,023	6	1.501×10^5
8	22,413	6	1.345×10^5
9	2,845	6	1.707×10^4
10	9,266	6	5.560×10^4
11	33,411	6	2.005×10^5
12	26,682	6	1.601×10^5
13	23,909	6	1.435×10^5
14	10,950	6	6.57×10^4
15	34,388	6	2.063×10^5
16	21,377	6	1.283×10^5
17	33,922	6	1.035×10^5
18	43,604	6	2.616×10^5
19	41,703	6	2.502×10^5
20	28,795	6	1.728×10^5
21	29,534	6	1.772×10^5
22	18,138	6	1.088×10^5
23	41,864	6	2.512×10^5
24	26,516	6	1.591×10^5
25	27,577	6	1.655×10^5
26	24,167	6	1.450×10^5

Table 7.9. (Continued)

Plant #	Critical hours (T_i)	Population of SHAS valves (N_i)	$T_i \times N_i$
27	6,353	6	3.812×10^4
28	20,988	6	1.259×10^5
29	6,065	6	3.639×10^4
30	1,729	6	1.037×10^4
31	19,473	6	1.168×10^5
32	6,448	6	2.869×10^4
33	42,928	6	2.576×10^5
34	24,012	6	1.441×10^5
35	545	6	3.27×10^3
36	28,896	6	1.734×10^5
37	37,182	6	1.631×10^5
38	44,756	6	2.685×10^5
Total	$N_i \times T_i = 5.279 \times 10^6$ hours		

SHAS may be calculated by using the information given in Tables 7.5 and 7.9 and equation 7.1

$$\lambda_H\ (M^*,S,C) = \frac{\sum_i f_i}{\sum_i N_i T_i}$$

where

M* = valve left open

S = SHAS (code SH)

C = valve (VX, VM)

$$\sum_i f_i = 2$$

$$\sum_i N_i T_i = 5.279 \times 10^6 \text{ hours}$$

$$\lambda_H(M^*,S,C) = \frac{2}{5.279 \times 10^6} = 3.8 \times 10^{-7}\ \text{hr}^{-1}$$

$$\text{HEP} = 6.37 \times 10^{-5} \quad .$$

The 90% confidence bounds on λ_H are

$$1.5 \times 10^{-7} \leq \lambda_H \leq 9.0 \times 10^{-7} \quad \text{per hour}$$

and

$$\underline{q} = 1.37 \times 10^{-4} \text{ per demand}$$

the 90% confidence bounds on $\underline{q}$ are

$$5.58 \times 10^{-5} \leq \underline{q} \leq 3.24 \times 10^{-4} \quad \text{per demand.}$$

7.3.4. Human error rates estimated for CHRS

7.3.4.1. CHRS valve mispositioning failure rate calculation The failure rate for valve mispositioning (clustering of all failure modes that lead to valves being mispositioning in the CHRS) may be calculated by using Tables 7.6 and 7.10. The critical hours are extracted from Appendix A.

The hourly failure rate of valves due to operator error is given by

$$\lambda_H(M,S,C) = \frac{\sum_i f_i}{\sum_i N_i T_i}$$

where

M = mispositioning

S = CHRS (code SB)

C = valve (code VO, VM)

$$\sum_i f_i = 2$$

$$\sum_i N_i T_i = 2.203 \times 10^7 \text{ hours}$$

$$\lambda_H(M,S,C) = \frac{2}{2.203} \times 10^{-7} = 9.0 \times 10^{-8} \text{ hr}^{-1}$$

$$\text{HEP} = 1.53 \times 10^{-5}$$

The 90% confidence bounds on λ_H are

$$5.0 \times 10^{-8} \leq \lambda_H \leq 2.1 \times 10^{-7} \text{ hr}^{-1} \quad .$$

The point estimate on $\underline{q}$ is

Table 7.10. Valve population, critical hours for all PWRs plants, CHRS (period from January 1, 1972, to January 1, 1978)

Plant #	Critical hours (T_i)	Population of CHRS valves (N_i)	$T_i \times N_i$
1	40,000	24	9.6×10^5
2	22,010	24	5.282×10^5
3	8,982	24	2.156×10^5
4	27,368	24	6.568×10^5
5	37,695	24	9.047×10^5
6	14,748	24	3.540×10^5
7	25,023	24	6.006×10^5
8	22,413	24	5.379×10^5
9	2,845	24	6.828×10^4
10	9,266	24	2.224×10^5
11	33,411	24	8.019×10^5
12	26,682	24	6.404×10^5
13	23,909	24	5.738×10^5
14	10,950	24	2.628×10^5
15	34,388	24	8.253×10^5
16	21,377	24	5.130×10^5
17	33,922	24	8.141×10^5
18	43,604	24	1.046×10^6
19	41,703	24	1.001×10^6
20	28,795	24	6.911×10^5
21	29,534	24	7.088×10^5
22	18,138	24	4.353×10^5
23	41,864	24	1.005×10^6
24	26,516	24	6.364×10^5
25	27,557	24	6.614×10^5
26	6,353	24	1.525×10^5
27	20,988	24	5.037×10^5

Table 7.10. (Continued)

Plant #	Critical hours (T_i)	Population of CHRS valves (N_i)	$T_i \times N_i$
28	6,065	24	1.456×10^5
29	1,729	24	4.150×10^4
30	19,473	24	4.674×10^5
31	6,448	24	1.548×10^5
32	42,928	24	1.03×10^6
33	24,012	24	5.763×10^5
34	545	24	1.308×10^4
35	28,896	24	6.935×10^5
36	37,182	24	8.934×10^5
37	44,756	24	1.074×10^6
Total	$N_i T_i = 2.203 \times 10^7$ hours		

$$\hat{q} = 3.29 \times 10^{-5} \text{ per demand}$$

and the 90% confidence bounds on q are

$$1.8 \times 10^{-5} \leq q \leq 7.75 \times 10^{-5} \text{ per demand.}$$

7.3.4.2. <u>CHRS valve left closed failure rate calculation</u> Using Tables 6.6 and 6.10 the failure rate for valves left closed in the CHRS may be calculated. The failure rate for valves due to operator error is given by

$$(M_1,S,C) = \frac{\sum_i f_i}{\sum_i N_i T_i}$$

where

M_1 = valve left closed

S = CHRS (SB)

C = valve (Code VO)

$\sum_i f_i = 1$

$\sum_i N_i T_i = 2.03 \times 10^7$ hours

$$\lambda_H\ (M_1,S,C) = \frac{1}{2.03 \times 10^7} = 5.0 \times 10^{-8}\ hr^{-1}$$

$$(HEP)_{M_1} = 8.27 \times 10^{-6}\ .$$

The 90% confidence bounds on λ_H are

$$1.75 \times 10^{-8} \leq \lambda_H \leq 1.5 \times 10^{-7}\ hr^{-1}\ .$$

The point estimate on q is

$$q = 1.77 \times 10^{-5} \text{ per demand}$$

and the 90% confidence bounds on $\underline{q}$ are

$$6.3 \times 10^{-6} \leq \underline{q} \leq 5.32 \times 10^{-5} \text{ per demand.}$$

Using the same calculation, the hourly failure rate and unavailability due to inadvertent closing of valves in the CHRS due to operator error would be the same as above, i.e.,

$$\lambda_H\ (M_2,S,C) = 5.0 \times 10^{-8}\ \text{hr}^{-1} \quad .$$

7.4. Comparison with Other Estimates of Human Error Probabilities

Human error probabilities (HEP) based on reported (LER) data (Section 7.3) will be compared with relevant estimates based on "expert estimates" reported in NUREG/CR-1278 and WASH-1400.

Tables 7.11 through 7.13 summarize the human error probability estimates listed in NUREG/CR-1278 (11) coded under the categories used to collect the LER data given in Appendix A. The tabled HEPs are given in more detail in Appendix B. The estimates in those tables deal with valve manipulation errors in those systems described in Section 5.3. The number of reported events dealing with relevant human failure modes and the corresponding values of HEP are listed in Tables 7.14, 7.15 and 7.16.

Based on the analysis given in Section 5, and since all failure modes given in Table 7.14 lead to mispositioning of valves due to human error, the estimated λ_D for

Table 7.11. Human error probabilities estimates from NUREG/CR-1278 for category #1 omission

Failure mode	HEP (per demand)	Lower bound	Upper bound
Did not open (left closed)			
Did not close (left open)			
ORAL INSTRUCTIONS			
Failure to carry out a specific oral instruction to change valve(s)			
Item(s) not written down by recipient			
One valve	$1x10^{-3}$	$5x10^{-4}$	$5x10^{-3}$
Two valves	$3x10^{-3}$	$1.5x10^{-3}$	$1.5x10^{-2}$
Three valves	$1x10^{-2}$	$5x10^{-4}$	$5x10^{-3}$
Four valves	$3x10^{-2}$	$1.5x10^{-3}$	$1.5x10^{-2}$
Five valves	$1x10^{-1}$	$5x10^{-3}$	$5x10^{-2}$
Item(s) written down by recipient failure to recall	$1x10^{-3}$	$5x10^{-4}$	$5x10^{-3}$
WRITTEN PROCEDURES			
Getting particular valve in sequence in:			
Short list (10 items) check off	$1x10^{-3}$	$1x10^{-4}$	$5x10^{-3}$
Short list, no check off	$3x10^{-3}$	$8x10^{-4}$	$1x10^{-2}$
Long list, check off	$3x10^{-3}$	$8x10^{-4}$	$1x10^{-2}$
Long list, no check off	$1x10^{-2}$	$1x10^{-3}$	$5x10^{-2}$
Misuse of the check off provision	$5x10^{-1}$	$1x10^{-1}$	$9x10^{-1}$
Plant procedures not followed, short cuts or personnel preferences followed instead	$1x10^{-2}$	$5x10^{-3}$	$5x10^{-2}$
Omission of one item from a list of valves or set of tags when written procedure is prepared	$3x10^{-3}$	$1.5x10^{-3}$	$1.5x10^{-2}$

Table 7.12. Human error probabilities estimates from NUREG/CR-1278 for category #2 incorrect commission

Failure mode	HEP (per demand)	Lower bound	Upper bound
Improper open/close			
Reversal errors			
The operator changes a valve that had already been changed and			
tagged	$1x10^{-4}$	$5x10^{-5}$	$1x10^{-3}$
not tagged	$1x10^{-1}$	$1x10^{-2}$	$5x10^{-1}$
Erroneous conclusion of valve status			
Rising-stem valve, the valve sticks at 3/4 its full stroke and there are			
local position indicator	$5x10^{-3}$	$2x10^{-3}$	$2x10^{-2}$
no position indicator	$1x10^{-3}$	$5x10^{-4}$	$1x10^{-2}$
All other valves, if there are			
local position indicator	$1x10^{-3}$	$5x10^{-4}$	$1x10^{-2}$
no position indicator	$1x10^{-2}$	$3x10^{-3}$	$1x10^{-2}$
position indicator elsewhere	$2x10^{-3}$	$1x10^{-3}$	$1x10^{-2}$
Improper operation			
Failure to complete change of state of MOV (holding time to switch is not adequate)	$3x10^{-3}$	$1x10^{-3}$	$1x10^{-2}$

Table 7.13. Human error probabilities estimates from NUREG/CR-1278 for category #3 inadvertence

Failure mode	HEP (per demand)	Lower bound	Upper bound
Inadvertent open/closure			
Manipulation of wrong valve (normal or remote actuated) where the intended valve is among similar appearing valves	$5x10^{-3}$	$2x10^{-3}$	$2x10^{-2}$
Manipulation of wrong MOV switch or circuit breaker where the intended item is among similar appearing ones	$3x10^{-3}$	$1x10^{-3}$	$1x10^{-2}$
Listing error of valves or set of tags when written procedure is prepared	$3x10^{-3}$	$1.5x10^{-3}$	$1.5x10^{-2}$
Tagging wrong MOV where the intended one is among similar ones	$5x10^{-3}$	$2x10^{-3}$	$2x10^{-2}$

Table 7.14. Reported events for CSIS

Failure mode	# of events	HEP from Tables 7.11 thru 7.13	Remarks
Did not close/open	3	$1x10^{-3}$	Assuming there are short lists with check off (very conservative)
Did not open/close	2	$1x10^{-3}$	
Did not verify	2	$1x10^{-3}$	
Misalignment	1	$5x10^{-3}$	

Table 7.15. Reported events for SHAS

Failure mode	# of events	HEP per demand from Tables 7.11-7.13	Remarks
Did not close/open	2	10^{-3}	Assuming there are short lists with check off
Communication	1	10^{-3}	

Table 7.16. Reported events for CHRS

Failure mode	# of events	HEP per demand from Tables 7.11-7.13	Remarks
Did not open/close	1	10^{-3}	Assuming there are short lists with check off
Inadvertent closing	1	5×10^{-3}	

mispositioning of valves in the CSIS is

$$\lambda_D = \frac{1 \times 5 \times 10^{-3} + 3 \times 10^{-3} + 2 \times 10^{-3} + 2 \times 10^{-3}}{8}$$

$$= 1.5 \times 10^{-3} \text{ per demand.}$$

Assuming a recovery factor of 0.1 (failure of checker to discover the error),

$$\lambda = \lambda_D \times 0.1$$
$$= 1.5 \times 10^{-3} \times 0.1 = 1.5 \times 10^{-4} \text{ per demand.}$$

This value is within a factor of two of the operator error probability of 2.857×10^{-4} per demand based on the reported LER data for mispositioning of valves in the CSIS.

Using Table 7.14, the estimated λ_D for a valve left closed (event reported by LER) in the CSRS is given by

$$\lambda_D = 1 \times 10^{-3} \text{ per demand}$$

and by assuming a recovery factor of 0.1 (failure of checker to discover the error)

$$\lambda = \lambda_D \times 0.1$$
$$= 10^{-4} \text{ per demand.}$$

This value is within a factor of two of the operator error probabilities of 5.6×10^{-5} per demand based on the reported LER data for the failure mode, "did not open a valve in the CSRS."

Since all the failure modes given in Table 7.15 lead to mispositioning of valves due to human error, then the estimated λ_D for mispositioning of valves in the SHAS is:

$$\lambda_D = \frac{2 \times 10^{-3} + 10^{-3}}{3} = 10^{-3} \text{ per demand .}$$

Again by assuming a recovery factor of 0.1 (failure of checker to discover the error),

$$\lambda = \lambda_D \times 0.1$$
$$= 10^{-4} \text{ per demand.}$$

This value is within a factor of two of the operator error probabilities of 2.0 x 10^{-4} per demand based on the reported LER data for, "mispositioning of valves in the SHAS."

Since all the failure modes given in Table 7.16 lead to mispositioning of valves due to human error, then the estimated λ_D for mispositioning of valves in CHRS is

$$\lambda_D = \frac{10^{-3} + 5 \times 10^{-3}}{2} = 3 \times 10^{-3} \text{ per demand.}$$

Again by assuming a recovery factor of 0.1 (failure of checker to discover the error)

$$\lambda = \lambda_D \times 0.1$$
$$= 3 \times 10^{-4} \text{ per demand.}$$

This value, which represents the unavailability of valves due to mispositioning due to operator error, is within a factor of ten of the operator error probabilities of 3.268 x 10^{-5} per demand based on the reported LER data for, "mispositioning of valves in the CHRS."

7.5. Discussion of the Results

Operator error rates are estimated here for the failure mode involving valving errors for those PWRS systems involved in the S_2C accident sequence. The estimated operator error rates will be compared with relevant estimates based on "expert estimates" reported in NUREG/CR-1278 (11) and in WASH-1400 (1).

The estimated operator errors presented in Sections 7.3 and 7.4 are summarized in Tables 7.17 and 7.18. As can be seen by inspection of Table 7.17 for the first four failure modes using LER data, the estimated operator error rates are approximately within a factor of 30 of those predicted using data from NUREG/CR-1278, but for the last two failure modes (valve left closed and valve inadvertently closed in CHRS), the estimated operator error rates based on LER data are significantly lower than those estimated using NUREG/CR-1278 data. As can be seen by inspection of the results given in Table 7.18, the HEPs estimates of the CSIS, CSRS and CHRS using LERs are within a factor of 10 or less of those predicted using data from WASH-1400 and NUREG/CR-1278, but for the SHAS using LERs data, the HEPs estimates are within a factor of 30 or less of those predicted using data from the other two sources.

It must be noticed that the estimates given here are based on the reactor years surveyed (January 1972 to January 1978) which doesn't cover all LER data. Therefore, more precise error rate estimates could be obtained by considering a larger sample of LER data which covers all reactor-years of experience up to date.

Table 7.17. Operator error rates estimates comparison

Failure mode	Operator error rate (λ) hr^{-1} Using LER data	Operator error rate (λ) hr^{-1} Using NUREG/CR-1728
Valve left closed in CSIS	$\lambda_U = 4.7 \times 10^{-7}$ $\lambda_M = 2.0 \times 10^{-7}$ $\lambda_L = 8.0 \times 10^{-8}$	$(\lambda)_U = 1.03 \times 10^{-5}$ $(\lambda)_M = 6.25 \times 10^{-6}$ $(\lambda)_L = 3.26 \times 10^{-6}$
Valve left open in CSIS	$\lambda_U = 6.3 \times 10^{-7}$ $\lambda_M = 3.0 \times 10^{-7}$ $\lambda_L = 1.4 \times 10^{-7}$	$(\lambda)_U = 1.03 \times 10^{-5}$ $(\lambda)_M = 6.25 \times 10^{-6}$ $(\lambda)_L = 3.26 \times 10^{-6}$
Valve left closed in CSRS	$\lambda_U = 4.7 \times 10^{-7}$ $\lambda_M = 1.5 \times 10^{-7}$ $\lambda_L = 5.5 \times 10^{-8}$	$(\lambda)_U = 1.25 \times 10^{-5}$ $(\lambda)_M = 4.17 \times 10^{-6}$ $(\lambda)_L = 1.48 \times 10^{-6}$
Valve left open in SHAS	$\lambda_U = 9.0 \times 10^{-7}$ $\lambda_M = 3.8 \times 10^{-7}$ $\lambda_L = 1.5 \times 10^{-7}$	$(\lambda)_U = 1.25 \times 10^{-5}$ $(\lambda)_M = 4.17 \times 10^{-6}$ $(\lambda)_L = 1.48 \times 10^{-6}$

Table 7.17. (Continued)

Failure mode	Operator error rate (λ) hr^{-1}	Operator error rate (λ) hr^{-1}
	Using LER data	Using NUREG/CR-1728
Valve left closed in CHRS	$\lambda_U = 1.5 \times 10^{-7}$	$(\lambda)_U = 2.97 \times 10^{-5}$
	$\lambda_M = 5.0 \times 10^{-8}$	$(\lambda)_M = 1.25 \times 10^{-5}$
	$\lambda_L = 1.75 \times 10^{-8}$	$(\lambda)_L = 5.10 \times 10^{-6}$
Valve inadvertently closed	$\lambda_U = 1.5 \times 10^{-7}$	$(\lambda)_U = 2.97 \times 10^{-5}$
	$\lambda_M = 5.0 \times 10^{-8}$	$(\lambda)_M = 1.25 \times 10^{-5}$
	$\lambda_L = 1.75 \times 10^{-8}$	$(\lambda)_L = 5.10 \times 10^{-6}$

Table 7.18. Human error probability (HEP) estimate for valve mispositioning in those systems involved in the S_2C sequence

System	Using LER data		WASH-1400[a]	NUREG/CR-1728
	Operator error rate (hr^{-1})	HEP	HEP	HEP
CSIS	$\lambda_U = 1.31 \times 10^{-6}$	$q_U = 4.70 \times 10^{-4}$	$q_U = 7.8 \times 10^{-3}$	$q_U = 2.47 \times 10^{-4}$
	$\lambda_M = 7.94 \times 10^{-7}$	$q_M = 2.86 \times 10^{-4}$	$q_M = 2.4 \times 10^{-3}$	$q_M = 1.50 \times 10^{-4}$
	$\lambda_L = 4.66 \times 10^{-7}$	$q_L = 1.68 \times 10^{-4}$	$q_L = 1.0 \times 10^{-3}$	$q_L = 7.83 \times 10^{-5}$
CSRS	$\lambda_U = 4.7 \times 10^{-7}$	$q_U = 1.82 \times 10^{-4}$	$q_U = 9.0 \times 10^{-4}$	$q_U = 3.00 \times 10^{-4}$
	$\lambda_M = 1.56 \times 10^{-7}$	$q_M = 5.61 \times 10^{-5}$	$q_M = 1.0 \times 10^{-4}$	$q_M = 1.00 \times 10^{-4}$
	$\lambda_L = 5.5 \times 10^{-8}$	$q_L = 2.0 \times 10^{-5}$	$q_L = 2.5 \times 10^{-5}$	$q_L = 3.55 \times 10^{-5}$
SHAS	$\lambda_U = 1.2 \times 10^{-6}$	$q_U = 4.3 \times 10^{-4}$	$q_U = 1.1 \times 10^{-2}$	$q_U = 3.0 \times 10^{-4}$
	$\lambda_M = 5.7 \times 10^{-7}$	$q_M = 2.05 \times 10^{-4}$	$q_M = 5.9 \times 10^{-3}$	$q_M = 1.00 \times 10^{-4}$
	$\lambda_L = 2.6 \times 10^{-7}$	$q_L = 9.32 \times 10^{-5}$	$q_L = 3.6 \times 10^{-3}$	$q_L = 3.55 \times 10^{-5}$
CHRS	$\lambda_U = 2.1 \times 10^{-7}$	$q_U = 7.75 \times 10^{-5}$	$q_U = 3.0 \times 10^{-4}$	$q_U = 7.17 \times 10^{-4}$
	$\lambda_M = 9.0 \times 10^{-8}$	$q_M = 3.27 \times 10^{-5}$	$q_M = 8.5 \times 10^{-5}$	$q_M = 3.00 \times 10^{-4}$
	$\lambda_L = 5.0 \times 10^{-8}$	$q_L = 1.8 \times 10^{-5}$	$q_L = 3.0 \times 10^{-5}$	$q_L = 2.23 \times 10^{-4}$

[a]From WASH-1400, Appendix II, Table II 1-2.

8. QUANTITATIVE EVALUATION OF SYSTEMS INVOLVED IN S_2C ACCIDENT SEQUENCE

8.1. Introduction

Nuclear reliability analysis is important since it is usually done for the purpose of safety assurance of NPPs. Quantitative nuclear reliability analysis is usually concerned with:

(a) Identifying the weaknesses and strengths of system behavior with respect to a given system objective;

(b) Pointing out the sensitivity of the system reliability performance to maintenance, testing, human factors, and hardware quality; and

(c) Determining relevant system reliability characteristics such as the unavailability and the unreliability.

The analysis presented in this chapter represents the first attempt at using calculated human error rates (Section 7) to analyze the fault trees of those systems involved in the S_2C accident sequence. Two systems were selected for the purpose of this analysis. Those systems are the CSIS and the CHRS. Functions and descriptions of both systems are given in Section 5.3. Fault tree analyses are used in reactor reliability analysis. Description of fault tree analysis and its applications is presented in Section 8.2.

The constructed fault trees given in WASH-1400 (1) for the CSIS and CHRS will be reconstructed here in such a way that those failure modes which do not have related human events or actions, are grouped in a single component. Those reconstructed fault trees are presented in Sections 8.3 and 8.4. The PREP and KITT codes are used to analyze those trees to determine the overall system unavailability. The description of the codes is presented in Section 8.3.2. The calculated human error rates presented in Chapter 7 and component failure rates found in WASH-1400 (1) were used as input for the PREP codes . This is presented in Section 8.3.3. The KITT-1 results are presented in Section 8.3.4.

An identical analysis is presented in Section 8.4 for the CHRS fault tree.

8.2. Fault Tree Analysis and its Applications

8.2.1. Fault Tree Analysis (FTA)

Fault Tree Analysis is a formalized deductive analysis technique that provides a systematic approach to investigate the possible modes of occurrences of a defined system state or undesired event. In other words, a fault tree is a logical diagram of the sequences of events which lead from one or more causal events upward to one consequence or resultant single failure. This failure is called the "Top Failure", "Final Failure", "System Failure" or "Top Event" A fault tree may be alternatively defined as a logical diagram which traces a top failure to basic failure causes (54).

FTA consists of two major steps: (1) the construction of the fault tree, and (2) its evaluation. The evaluation of the fault tree can be qualitative (55), quantitative (55, 56), or both depending upon the scope and extensiveness of the analysis.

The objectives of fault tree analysis are: (1) to define critical paths in the accident analysis, (2) to calculate probabilities of failures leading to given consequences or of consequences occurring in the system from one or a number of different initiating faults, and (3) to specify safeguard systems to protect against damaging consequences for each failure branch of the tree (55).

8.2.2. Event symbols

The symbols shown in Fig. 8.1 represent specific types of fault events in fault tree analysis (57). The rectangle defines an event that is the output of a logic gate. The logic gates for fault tree construction are the OR and the AND gates. The OR gate describes a situation where the output event will exist if one or more of the input events exist. The AND gate describes the logical operation

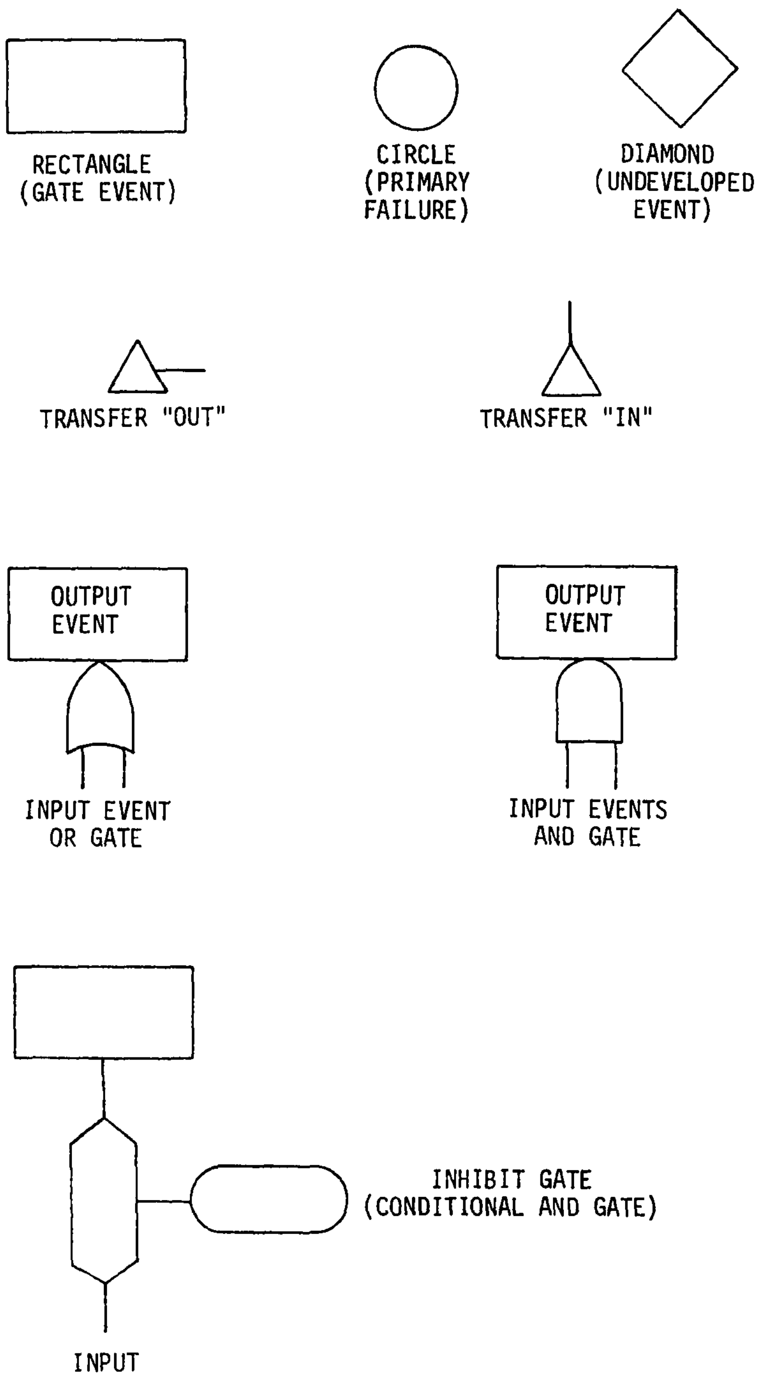


Figure 8.1. Specific types of fault events and fault event codes used in CSIS and CHRS fault trees analysis

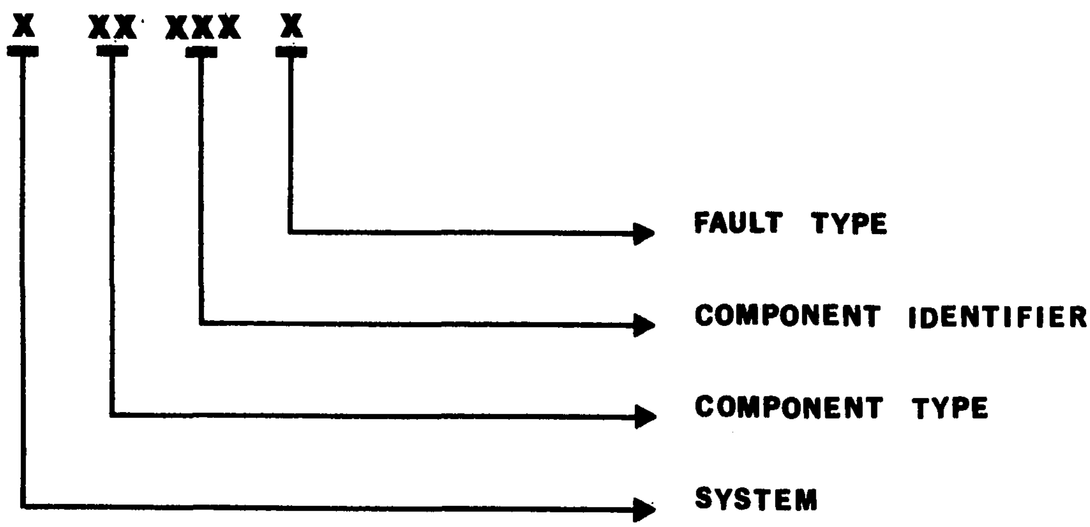


Figure 8.1 (Continued)

Code	System	Code	Component type	Code	Failure type
A	Containment	MV	Manual valve	A	Operator error
	Spray Injection	OV	Motor operating valve	B	Short circuit
	(CSIS)	LF	Line filter	C	Inadvertently closes
		CL	Clutch	D	Plugged
		EM	Electric motor	E	Disengages
B	Containment	PM	Pump	F	No sufficient torque
	Limiting Control	CV	Check valve	G	Fail to start
	(CLCS)	NZ	Nozzles	H	Discontinues running
		TC	Train circuit	I	Fail to close
C	Containment heat	CB	Circuit breaker	J	Fail to command
	removal	CC	Control circuit	K	No power
	(CHRS)	TK	Tank	L	Rupture
		VT	Vent	M	Leakage
		AV	Air vent	N	Off-site power
		HE	Heat exchanger	O	Fail to read
		SN	Sensor	P	Insufficient voltage
		BS	Bus	Q	Inhibits flow
		CV	Control value		

Figure 8.1 (Continued)

that requires the coexistence of all input events to produce the output event. The symbols for the logic gates are shown in Fig. 8.1. The circle defines a basic inherent failure of a system element when operated within its design specifications. It is, therefore, a primary failure. The diamond represents a failure other than a primary failure that is purposely not developed further.

The inhibit gate is essentially a one-input AND gate that describes a causal relationship between one fault and another. The inhibit gate defines a situation where the coexistence of an input event and a conditional event is necessary for the output event to occur. Fig. 8.1 also shows a breakdown of the fault tree identification code and fault events codes which are used here for listing of failures on the trees.

8.2.3. Application of fault trees

After constructing the fault tree, an evaluation of the critical path is carried out. A critical path (mode failure) is the smallest set of primary failures such that if all these primary failures simultaneously exist, then the top failure exists. The mode failures of a fault tree can be obtained by a number of methods. A detailed description of the methods is given in references (56, 58).

With knowledge of the failure modes of the fault tree, the evaluation can then proceed to a study of the probabilistic characteristics of the primary failures, mode failures, and the top failure.

In order to obtain this probability, the component behavior data in the form of failure rates $\lambda(t)$ and repair times $\mu(t)$ are required as inputs to the system models. On the other hand, for any reliability or fault tree study, the quantities $\lambda(t)$ and $\mu(t)$, or their equivalent, must be known for every primary failure of the fault tree. If the primary failure is the failure of a component, then $\lambda(t)$ and $\mu(t)$ are termed the component failure rate and component repair rate, respectively.

From $\lambda(t)$ and $\mu(t)$, some probabilistic quantities may be obtained which quantify, or characterize, the particular primary failure. The probability $A(t_1,t)$ of the primary failure first occurring in time t to t+dt, given that it does not exist at time t_1, is given by (59)

$$A(t_1,t)dt = \exp[-\int_{t_1}^{t} \lambda(t_2)dt_2]\lambda(t)dt \qquad (8.1)$$

where

$\lambda(t)dt$ = the probability of the failure occurring in time t to t+dt, given the failure is not existing at time t .

It is clear from equation 8.1 that the probability $F(t_1,t)$ that the primary failure doesn't occur from time t_1 to t is simply

$$F(t_1,t) = \exp[\int_{t_1}^{t} \lambda(t_2)dt_2];\ t_1 \le t\ . \qquad (8.2)$$

In the context of the defined failure, the failure probability is equivalent to unreliability

With regard to repair, the probability that the primary failure is repaired at time t to t+dt, given that it exists at time t_1, $B(t_1,t)dt$, is given by (59)

$$B(t_1,t)dt = \exp[-\int_{t_1}^{t} \mu(t_2)dt_2]\mu(t)dt; \quad t_1 \leq t \tag{8.3}$$

where

$\mu(t)dt$ = the probability of the failure being repaired in time t to t+dt given that the failure exists at time t.

The quantity $A(t_1,t)$ and $B(t_1,t)$ are termed the first failure distribution and the repair distribution, respectively. The term $F(t_1,t)$ is called the nonfailure probability.

There are two other primary failure characteristics, besides the above, which are essential for any reliability study or fault tree evaluation. The first characteristic is the primary failure intensity $w(t)$, which is defined as

$w(t)$ = the expected number of times the primary failure occurs at time t per unit time.

By using this definition, it is clear that the expected number of times the primary failure occurs in any interval from t_1 to t, $w(t_1,t)$ is (59)

$$w(t_1,t) = \int_{t_1}^{t} w(t_2)dt_2 \ . \tag{8.4}$$

By assuming that (initial condition) at t=0 the primary failure does not exist, an equation for w(t) in terms of the data for the primary failure can be obtained,

$$w(t) = A(0,t) + \int_0^t dt_2 w(t_2) \int_{t_2}^t dt_1 B(t_2,t) A(t_1,t) \qquad (8.5)$$

where

A(0,t) is the contribution to w(t) from the first occurrence of the primary failure.

The second primary failure characteristic of interest is the primary failure existence probability q(t). The probability of the primary failure not existing at time t is merely 1-q(t). By using the definition of $\lambda(t)$ and w(t), it is clear that (59)

$$w(t) = [1-q(t)]\lambda(t), \qquad (8.6)$$

or

$$q(t) = 1 - \frac{w(t)}{\lambda(t)} . \qquad (8.7)$$

It was stated previously that a mode failure or critical path is the smallest set of primary failures such that if all these primary failures exist at time t the mode failure (and top failure) exists at time t.

Consider a particular mode failure that consists of n primary failures and let these constituent primary failures be designated with indices from 1 to n. Assume the primary failures are independent and that at t=0 they all do not exist. The first characteristic obtained for the mode failure will be the mode failure existence probability, $Q(t)$, defined as

$Q(t)$ = the probability that the mode failure exists at time t.

Since the mode failure exists at time t and if and only if all its primary failures exist at time t, then

$$Q(t) = \prod_{\alpha=1}^{n} q_j(t) \, , \tag{8.8}$$

where $q_j(t)$ is the existence probability for the jth primary failure of the mode failure. The mode failure nonexistence probability, $p(t)$, is then just $1-Q(t)$ and is the probability of the mode failure not existing at time t; in terms of the constituent primary failures, $p(t)$ is the probability of one or more of these primary failures not existing at time t. Equation 8.8 allows $Q(t)$, or $p(t)$, to be simply determined from the primary failure information.

The existence probability $Q(t)$ is of significance to the top failure to which the particular mode failure contributes. If the mode failure exists at time t, then the top failure exists at time t. Examination of the $Q(t)$ for all the mode failures (critical paths) of the fault tree will yield those critical mode failures by which the top failure is most likely to exist.

More detailed explanations for this and other mode failure characteristics and top failure information are given in reference (59).

8.3. CSIS Fault Tree "Insufficient Fluid Flow"

8.3.1. CSIS fault tree description

It is easy to understand the fault tree given in Fig. 8.2 by examining the simplified flow diagram of the CSIS which is given in Fig. 5.1.

The top event is considered to be insufficient fluid flow to the CSIS and this will be due to one of the following events (mode events in OR gate):

(1) Failures common to both subsystems cause insufficient spray delivery.

(2) Failures in subsystem A&B cause insufficient fluid flow.

As shown in Fig. 8.2, one out of two events should take place in order for the top event to occur.

It was assumed that each of the above mode events takes place due to failure of its particular components. To make the calculations tractable and to keep the significant events consistent with the resolution of the data available, the above fault tree is reduced before making any calculations. The reduced fault tree is shown in Fig. 8.3. The fault events code is given in Fig. 8.1. The events shown in Figs. 8.2 and 8.3 represent the following:

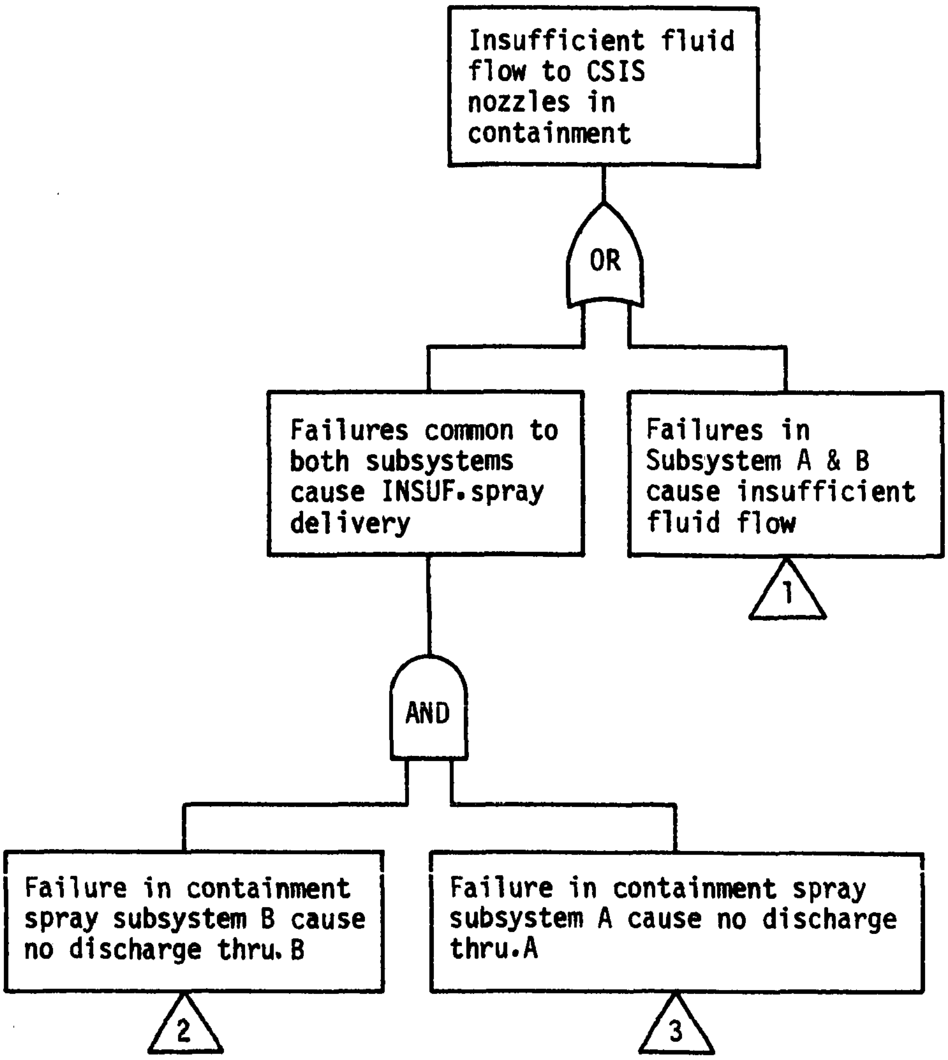


Figure 8.2. CSIS fault tree

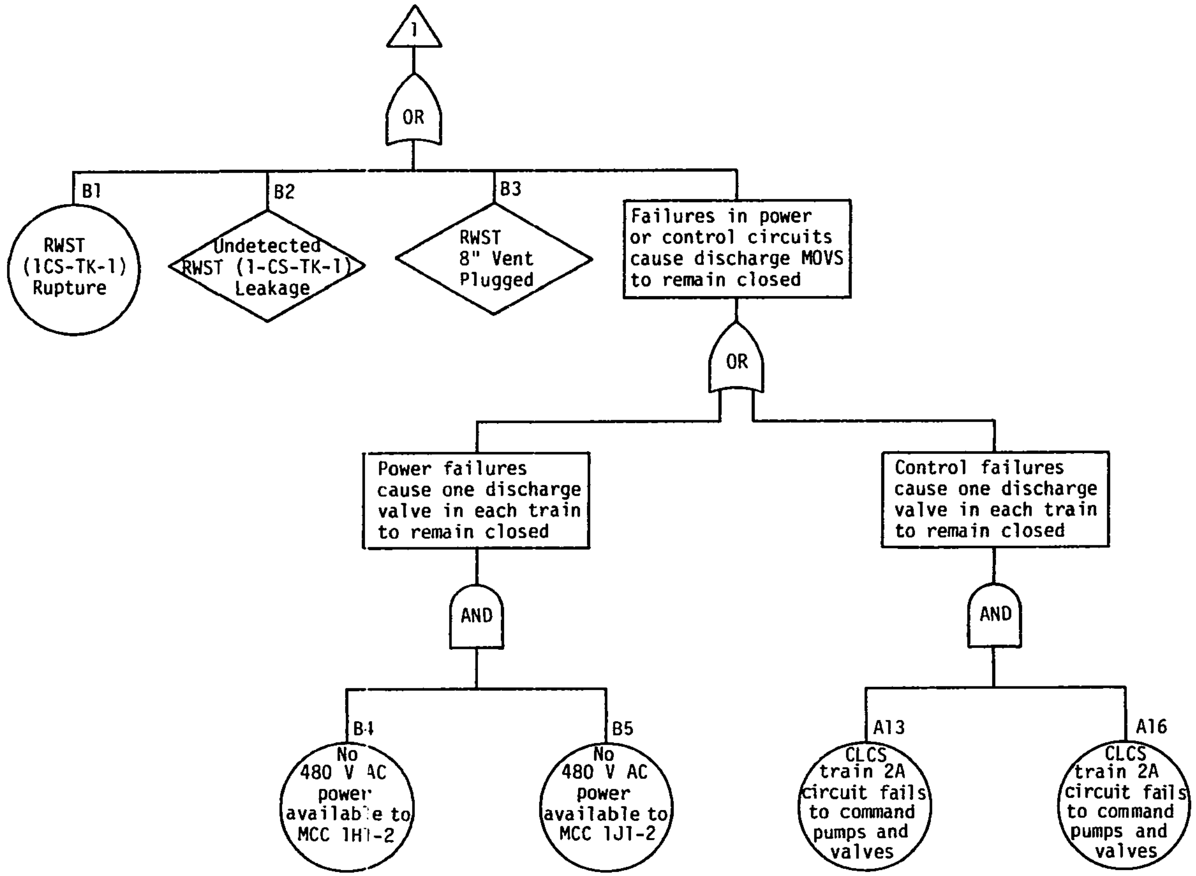


Figure 8.2. (Continued)

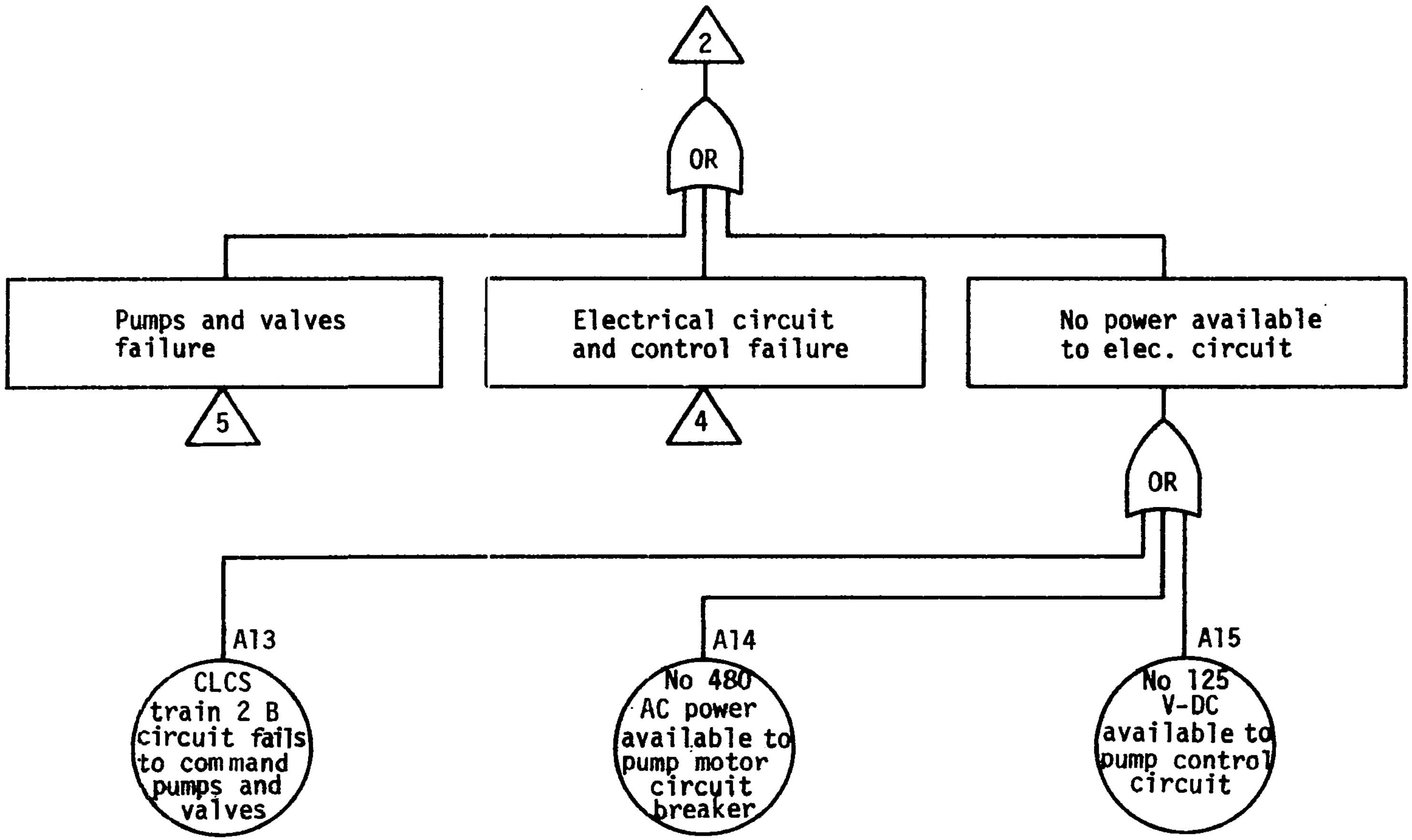
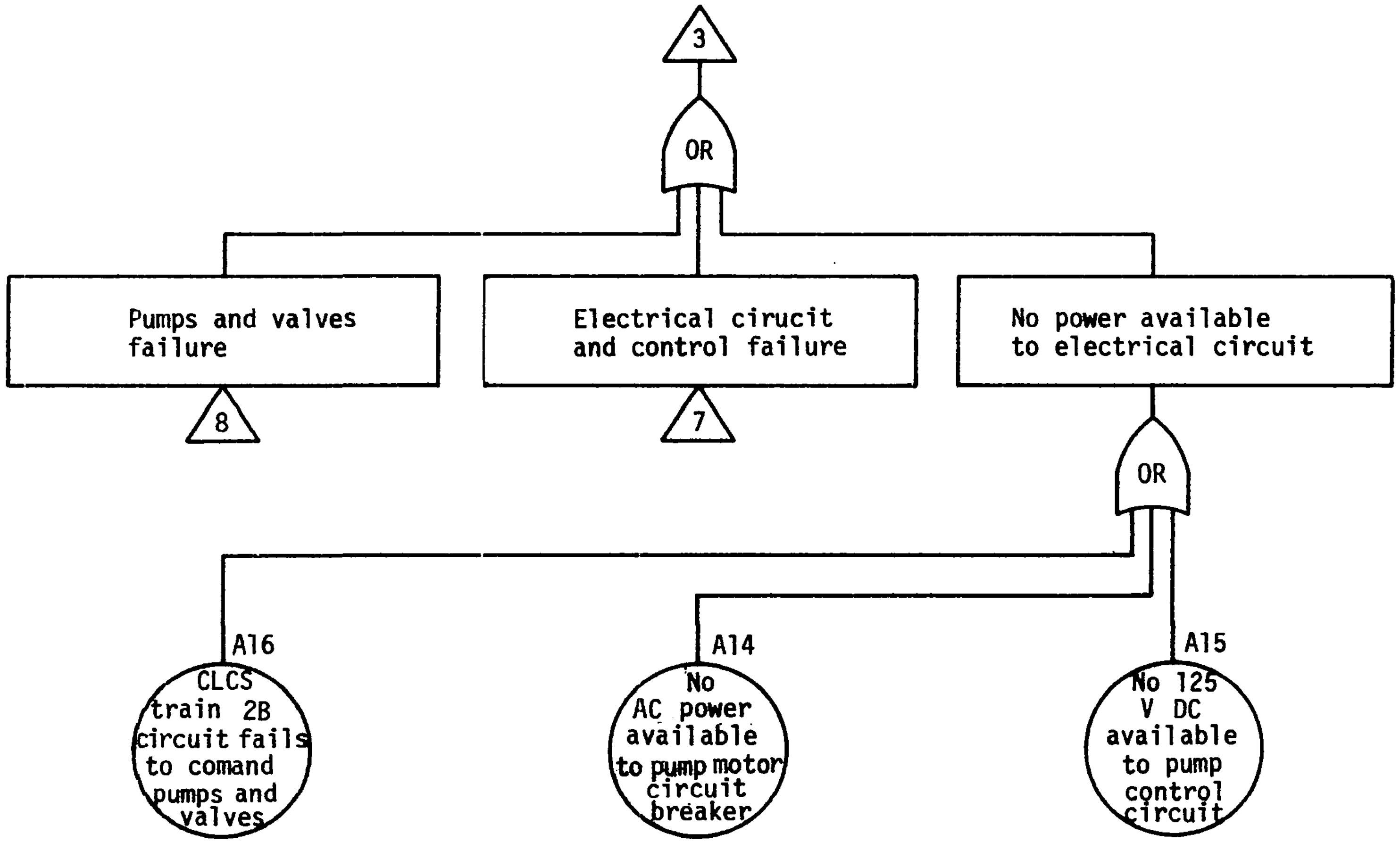


Figure 8.2. (Continued)



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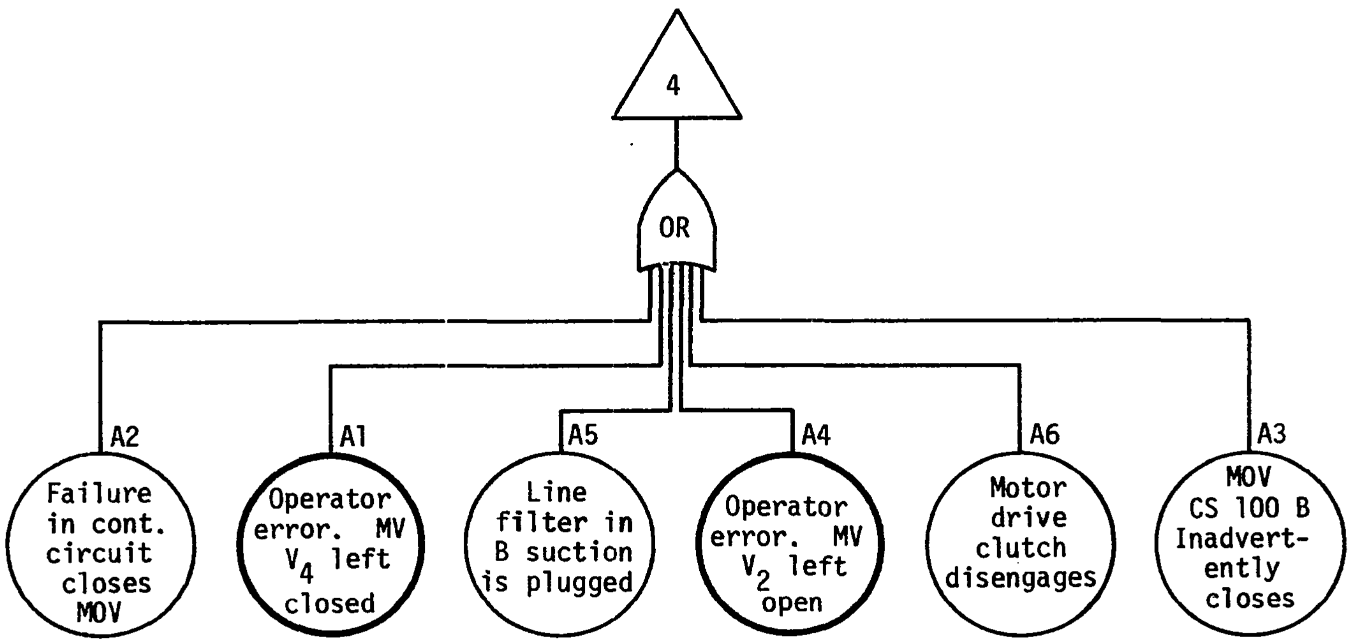

Figure 8.2. (Continued)

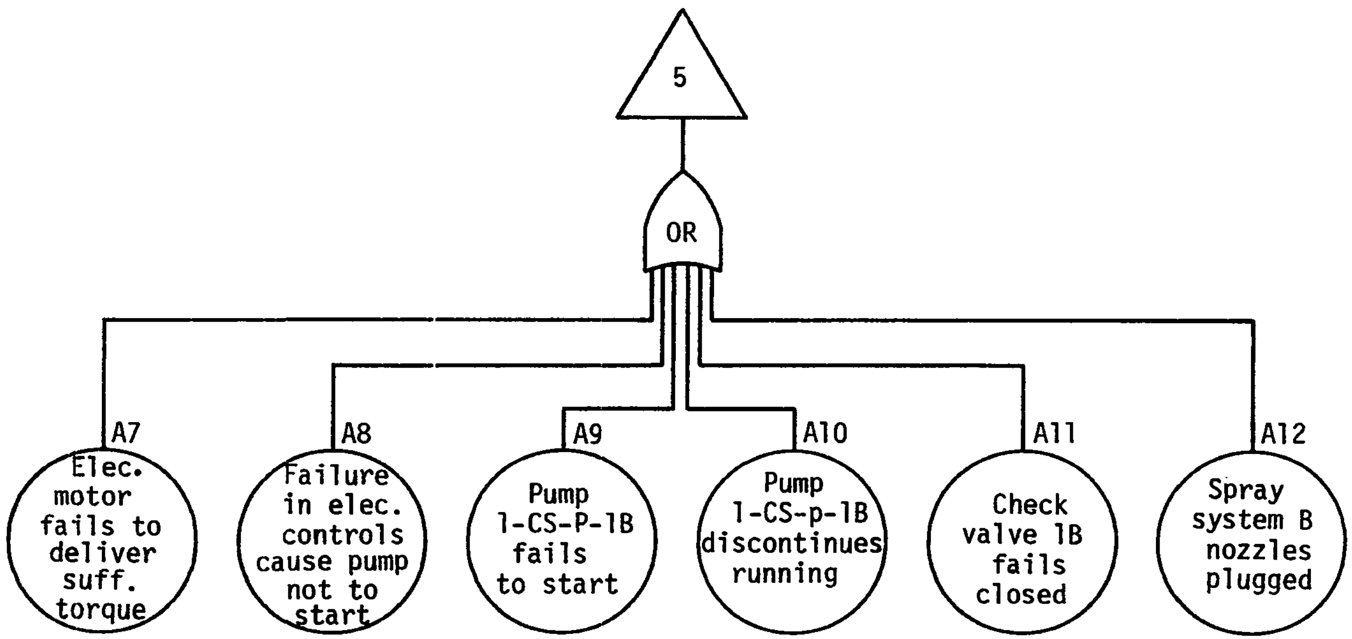

Figure 8.2. (Continued)

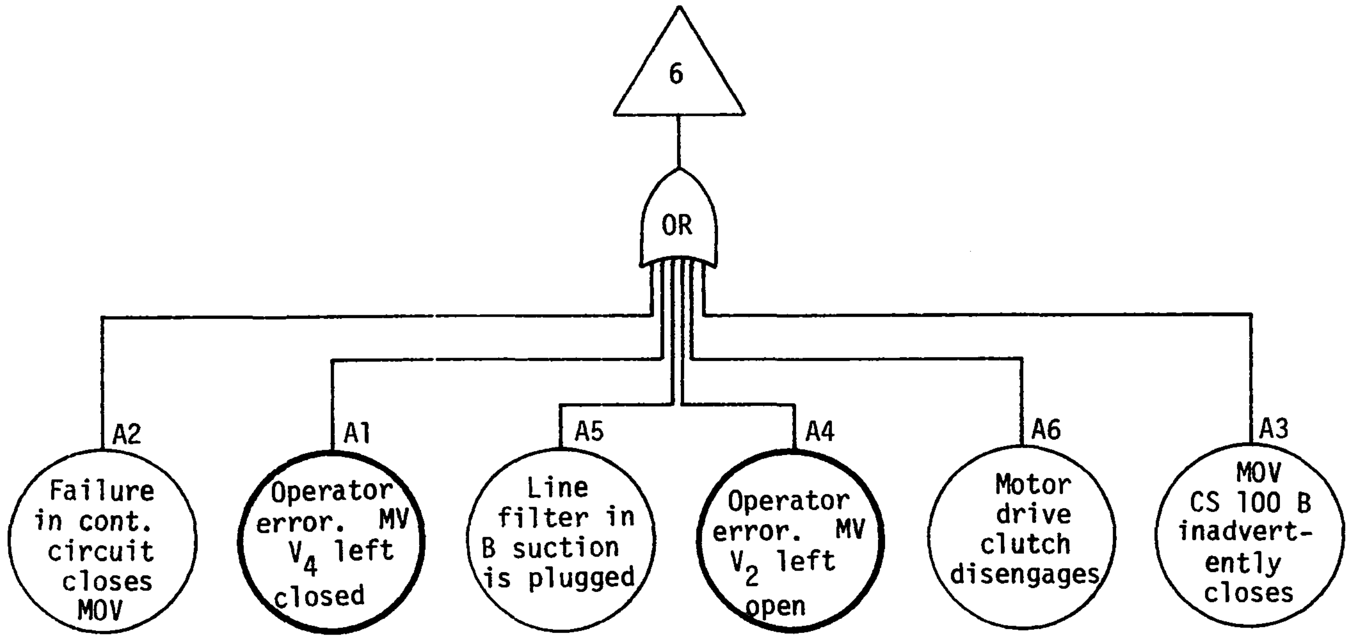

Figure 8.2. (Continued)

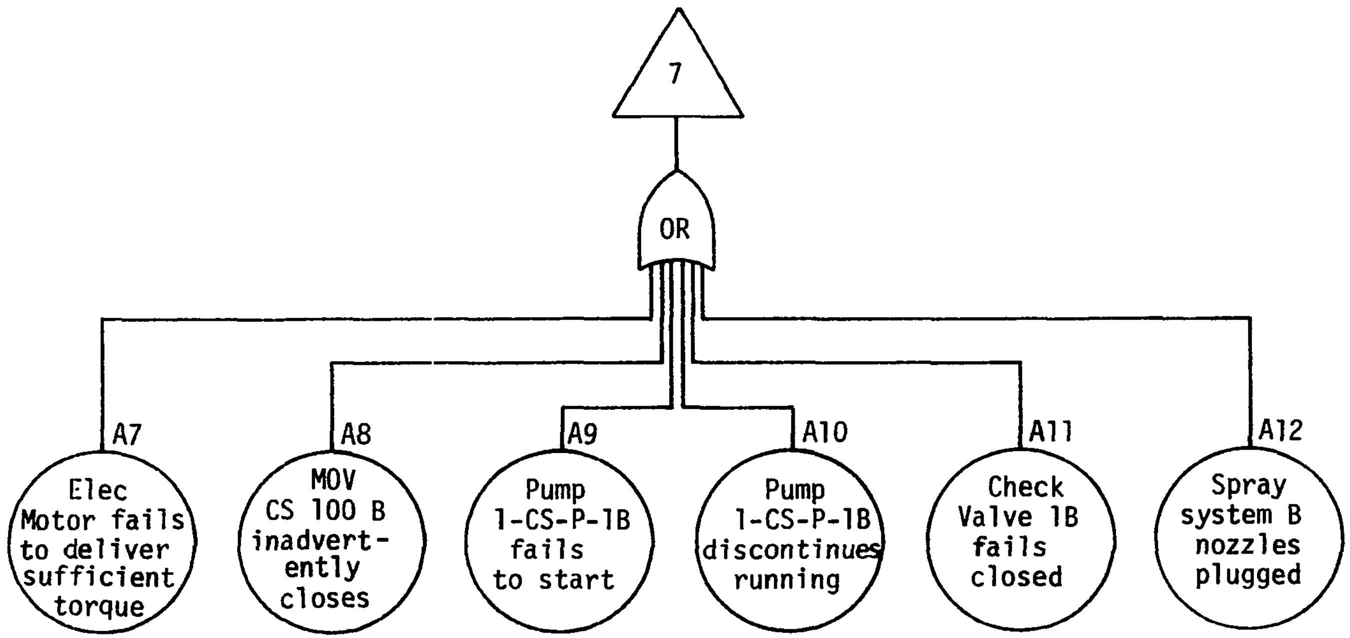

Figure 8.2. (Continued)

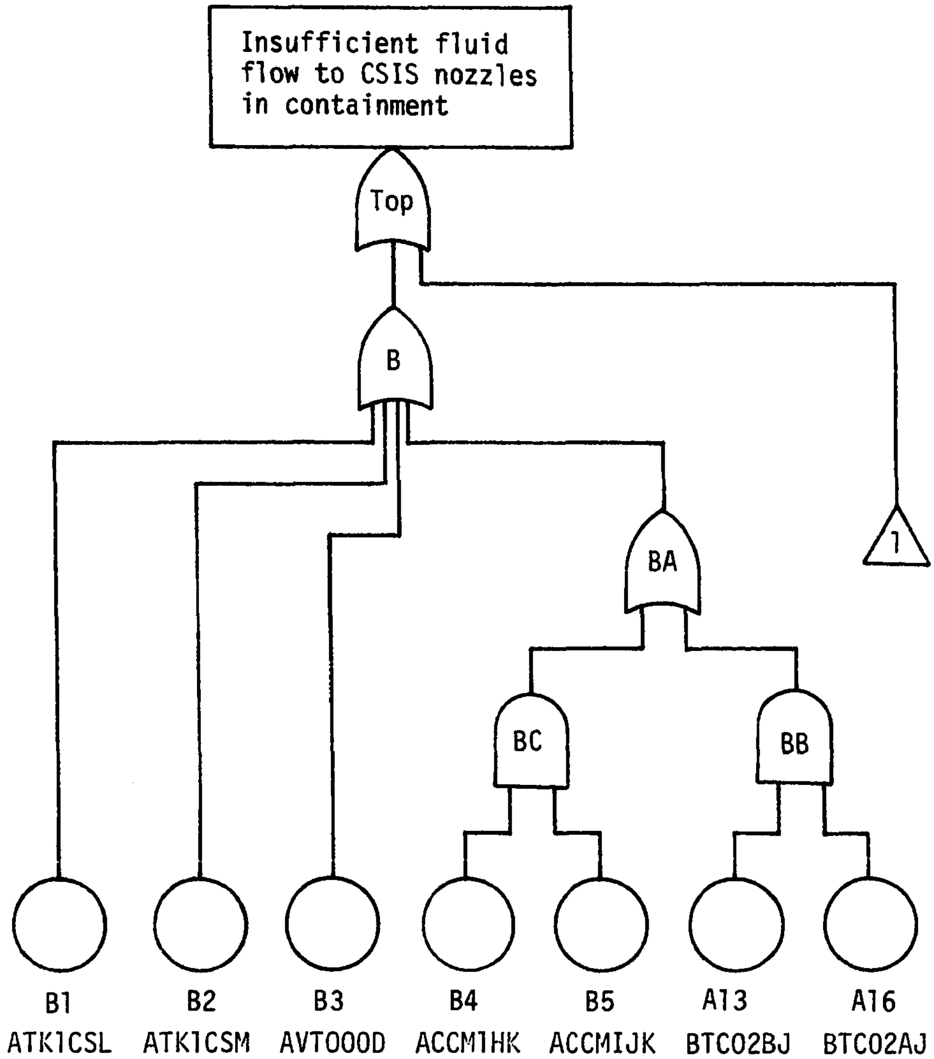

Figure 8.3. The simplified fault tree of the CSIS

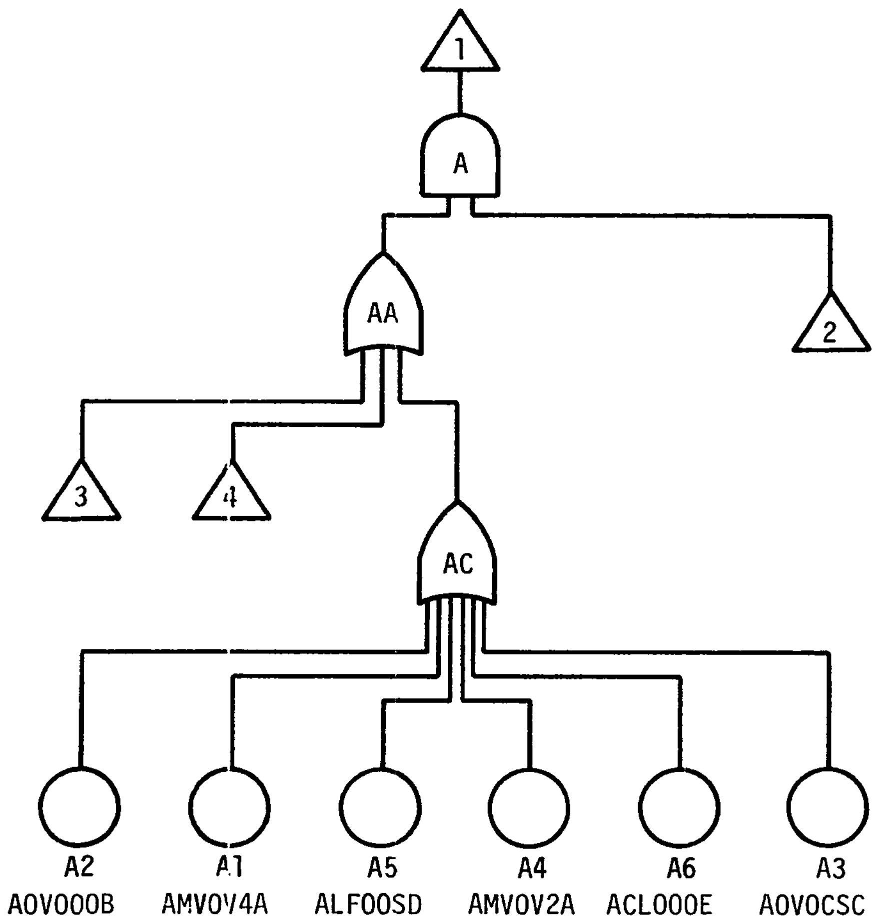

Figure 8.3. (Continued)

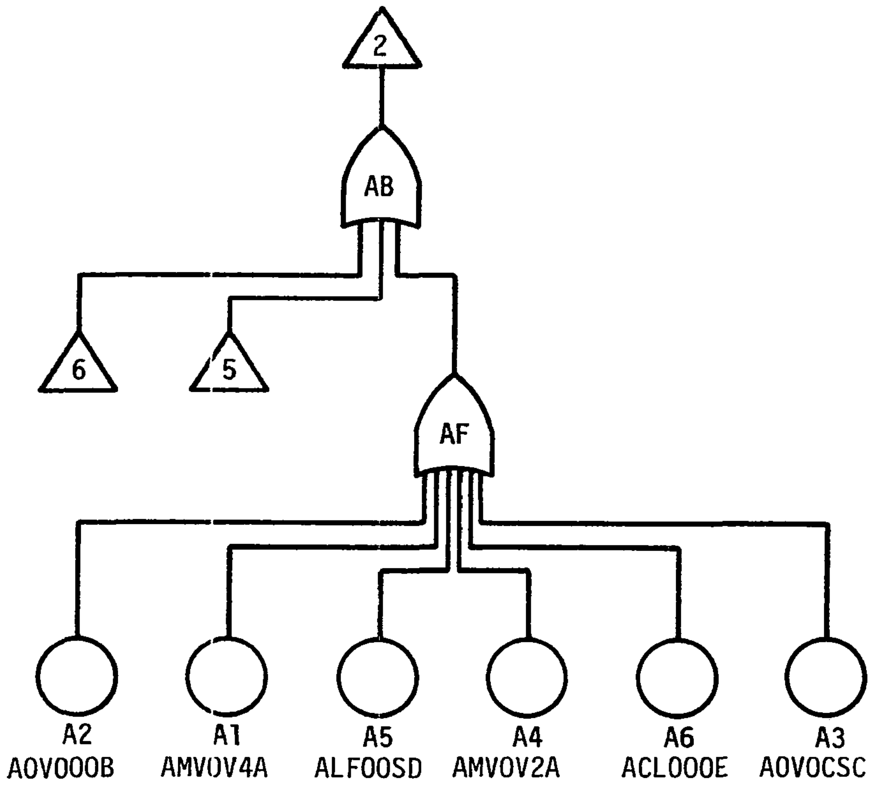

Figure 8.3. (Continued)

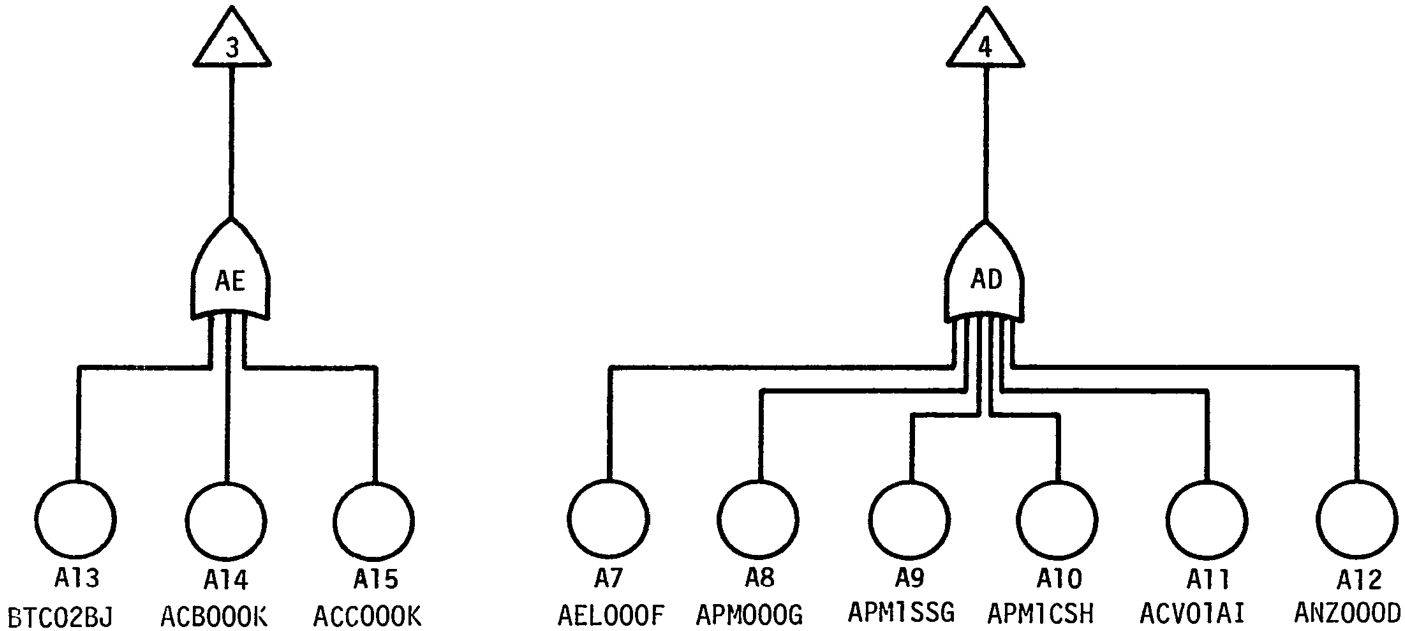

Figure 8.3. (Continued)

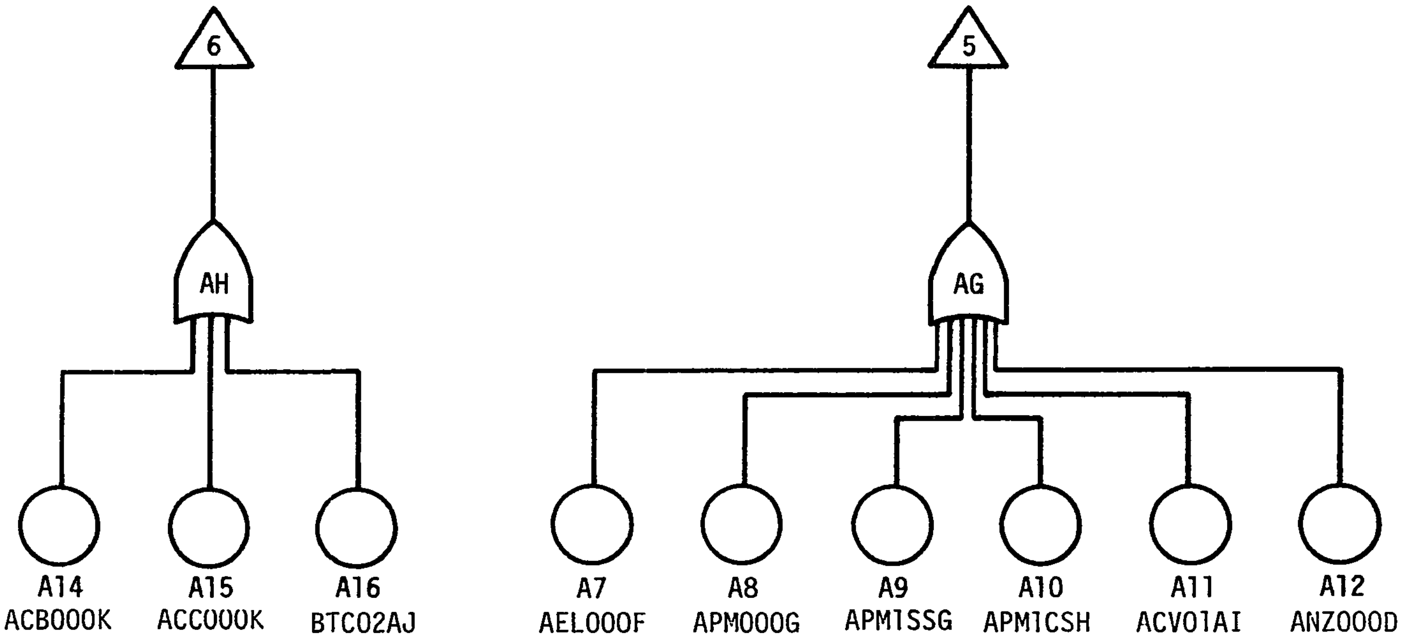

Figure 8.3. (Continued)

A1 = operator error. MV, V4 left closed = AMVOV4A;

A2 = failure in containment circuitry closes MOV = AOVOOOB;

A3 = MOV CS 100 A or B inadvertently closes = AOVOCSC;

A4 = operator error. MV, V2 is left open = AMVOV2A;

A5 = line filter in A or B suction is plugged = ALFOOSD;

A6 = motor drive clutch disengages = ACLOOOE;

A7 = electric motor fails to deliver sufficient torque = AELOOOF;

A8 = failure in electrical controls cause pump not to start = APMOOOG;

A9 = pump 1-SS-p-1B or 1A fails to start = APM1SSG;

A10 = pump 1-CS-p-1B or 1A discontinues running = APM1CSH;

A11 = check valve 1B or 1A fails to close = ACV01AI;

A12 = spray systems B or A nozzles plugged = ANZOOOD;

A13 = CLCS train 2B circuit fails to command pumps and valves BTCO2BJ;

A14 = no 480V-AC power available to pump motor circuit breaker = ACBOOOK;

A15 = no 125V-DC available to pump control circuit = ACCOOOK;

A16 = CLCS train 2A circuit fails to command pumps and valves = BTCO2AJ;

B1 = RWST (1CS-TK-1) rupture = ATK1CSL;

B2 = undetected RWST(1CS-TK-1) leakage = ATK1CSL;

B3 = RWST 8" vent plugged = AVTOOOD;

B4 = no 480V-AC power available to MCC 1H-2 = ACCMIHK;

B5 = no 480V-AC power available to MCC 1J1-2 = ACCMIJK.

8.3.2. PREP and KITT codes description

The PREP code is designed to accept an input description of the system's fault trees, generate the appropriate logical equivalent, and obtain the system's minimal cut or path sets. A minimal cut set is the smallest set of system components which, when failed, will cause the system to fail. A minimal cut set is defined to be in the failed or nonfunctioning state if and only if all of its components are in the failed state and is defined to be in the non-failed or functioning state if and only if at least one of its components is in the functioning state (58).

These minimal cut sets (failure mode) or the minimal path sets (success modes) can then be used by the KITT codes to obtain reliability information about the system. The PREP code is composed of two sections: TREBIL reads the input and generates the logical equivalent of the fault tree, and MINSET obtains the minimal cut or path sets of the tree. Detailed description of the PREP code and its input data is given in Appendix C (60).

After having obtained either the minimal cut sets or the minimal path sets, the fault tree is then evaluated by running the KITT code to obtain the probability characteristics of the components. These probability characteristics include: (1) the probability of the failure existing at time t (the "unavailability"); (2) the probability of the failure not occurring to the time t (the "reliability"); (3) the expected number of failures occurring to time t; (4) the failure rate at time t; and the failure intensity at time t (λ). Detailed description of the KITT code and its input data are given in Appendix D (60).

8.3.3. <u>The PREP run for the CSIS fault tree</u>

The simplified fault tree shown in Fig. 8.3 represents the input to the PREP codes. Each primary event on the fault tree is assigned an arbitrary unique name. Each gate is then coded on an input card. This card gives the name of the gates and/or primary event attached to the gate. Besides the simplified fault tree, the input data necessary to use the PREP codes are the component failure rate (lambdas) and repair times (taus).

The PREP codes were run three different times for three different cases. In the first case, WASH-1400 was used to estimate the values of the failure rate λ and the repair time τ. These values are listed in Table 8.1. The fault tree shown in Fig. 8.3 was analyzed using the PREP codes, and the results are shown in Fig. 8.4.

In the second case, WASH-1400 was also used to estimate the values of the failure rate λ and repair time τ except for human-related events. For those human-related events, (CP-A1 and CP-A4), the calculated human error rates using

Table 8.1. Estimated values of the failure rates/error rates and the repair time/recovery time for the components in Fig. 8.3 using data from WASH-1400

Component symbol	Failure rates/ error rates (λ) (hours^{-1})	Repair time/ recovery time (hours)
CP-A1	3×10^{-6}	360
CP-A2	0.0003×10^{-6}	10
CP-A3	0.25×10^{-6}	360
CP-A4	30×10^{-6}	360
CP-A5	0.3×10^{-6}	400
CP-A6	0.8×10^{-6}	400
CP-A7	0.03×10^{-6}	360
CP-A8	30×10^{-6}	360
CP-A9	30×10^{-6}	360
CP-A10	30×10^{-6}	360
CP-A11	28×10^{-6}	300
CP-A12	0.03×10^{-6}	4400
CP-A13	0.75×10^{-6}	400
CP-A14	0.028×10^{-6}	360
CP-A15	3.05×10^{-6}	360
CP-A16	13.0×10^{-6}	360
CP-B1	0.0001×10^{-6}	24
CP-B2	0.0001×10^{-6}	24
CP-B3	0.0001×10^{-6}	4400
CP-B4	0.028×10^{-6}	360
CP-B5	0.028×10^{-6}	360

```
****************************************************************
*TREBIL FALLT TREE BUILDING PROGRAM
****************************************************************


CSIS SAFTY ANALYSIS

NUMBER OF GATES,NG-------------------------   14

COMBO STARTING VALUE,MIN-------------------    1

COMBO ENDING VALUE,MAX---------------------    5

CUT SET - PATH SET SWITCH,IDEX1------------    0

PRINT - PUNCH SWITCH,IDEX2-----------------    1

MONTE CARLO STARTER,MCS--------------------    0

NO. OF RANDOM NUMBERS TO REJECT,NREJEC-----    0

NO. OF MONTE CARLO TRIALS,NTR--------------    0

MIXING PARAMETER SWITCH,IREN---------------    0

MONTE CARLO MIXING PARAMETER,TAA-----------.0
```

Figure 8.4. Output of PREP computations

```
*************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
*************************************************************************


CSIS SAFTY ANALYSIS

          THIS IS THE SUBROUTINE GENERATED BY TREBIL
      SUBROUTINE TREE
      LOGICAL TOP,A( 500),X( 500)
      COMMON/TREES/A,X,TOP
      A(    1) = X(    1).AND.X(    2)
      A(    2) = X(    3).AND.X(    4)
      A(    3) = X(    5).OR.X(    6).OR.X(    4)
      A(    4) = X(    7).OR.X(    8).OR.X(    9).OR.X(   10)
    *          .OR.X(   11).OR.X(   12)
      A(    5) = X(   13).OR.X(   14).OR.X(   15).OR.X(   16)
    *          .OR.X(   17).OR.X(   18)
      A(    6) = X(    3).OR.X(    5).OR.X(    6)
      A(    7) = X(    7).OR.X(    8).OR.X(    9).OR.X(   10)
    *          .OR.X(   11).OR.X(   12)
      A(    8) = X(   13).OR.X(   14).OR.X(   15).OR.X(   16)
    *          .OR.X(   17).OR.X(   18)
      A(    9) = A(    2).OR.A(    1)
      A(   10) = A(    5).OR.A(    4).OR.A(    3)
      A(   11) = A(    8).OR.A(    7).OR.A(    6)
      A(   12) = A(    9)
    *          .OR.X(   19).OR.X(   20).OR.X(   21)
      A(   13) = A(   11).AND.A(   10)
      A(   14) = A(   13).OR.A(   12)
      TOP = A(   14)
      RETURN
      END
```

Figure 8.4. (Continued)

```
********************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM                                            *
********************************************************************************
```

CSIS SAFTY ANALYSIS

COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	CP-B4	2.80000D-08	3.60000D 02
2	CP-B5	2.80000D-08	3.60000D 02
3	CP-A13	7.50000D-07	4.00000D 02
4	CP-A16	1.30000D-05	3.60000D 02
5	CP-A14	2.80000D-08	3.60000D 02
6	CP-A15	3.05000D-06	3.60000D 02
7	CP-A7	3.00000D-08	3.60000D 02
8	CP-A8	3.00000D-05	3.60000D 02
9	CP-A9	3.00000D-05	3.60000D 02
10	CP-A10	3.00000D-05	5.00000D-01
11	CP-A11	2.80000D-05	3.00000D 02
12	CP-A12	3.00000D-08	4.40000D 03
13	CP-A1	3.00000D-06	3.60000D 02
14	CP-A2	3.00000D-10	1.00000D 01
15	CP-A3	2.50000D-07	3.60000D 02
16	CP-A4	3.00000D-05	3.60000D 02
17	CP-A5	3.00000D-07	4.00000D 02
18	CP-A6	8.00000D-07	4.00000D 02
19	CP-B1	1.00000D-10	2.40000D 01
20	CP-B2	1.00000D-10	2.40000D 01
21	CP-B3	1.00000D-10	4.40000D 03

Figure 8.4. (Continued)

```
*********************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
*********************************************************************************


CSIS SAFTY ANALYSIS

NAME      TYPE      INPUTS----
TOP       OR    2 0 GT-A      GT-B
GT-A      AND   2 0 GT-AA     GT-AB
GT-B      OR    1 3 GT-BA     CP-B1     CP-B2     CP-B3
GT-AA     OR    3 0 GT-AC     GT-AD     GT-AE
GT-AB     OR    3 0 GT-AF     GT-AG     GT-AH
GT-AC     OR    0 6 CP-A1     CP-A2     CP-A3     CP-A4     CP-A5     CP-A6
GT-AD     OR    0 6 CP-A7     CP-A8     CP-A9     CP-A10    CP-A11    CP-A12
GT-AE     OR    0 3 CP-A13    CP-A14    CP-A15
GT-AF     OR    0 6 CP-A1     CP-A2     CP-A3     CP-A4     CP-A5     CP-A6
GT-AG     OR    0 6 CP-A7     CP-A8     CP-A9     CP-A10    CP-A11    CP-A12
GT-AH     OR    0 3 CP-A14    CP-A15    CP-A16
GT-BA     OR    2 0 GT-BB     GT-BC
GT-BB     AND   0 2 CP-A13    CP-A16
GT-BC     AND   0 2 CP-B4     CP-B5
END             0 0
```

Figure 8.4. (Continued)

```
***********************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
***********************************************************************************
```

CSIS SAFTY ANALYSIS

TREE INDEX	GATE NAME		INPUTS--					
1	GT-BC	AND	CP-B4	CP-B5				
2	GT-BB	AND	CP-A13	CP-A16				
3	GT-AH	OR	CP-A14	CP-A15	CP-A16			
4	GT-AG	OR	CP-A7	CP-A8	CP-A9	CP-A10	CP-A11	CP-A12
5	GT-AF	OR	CP-A1	CP-A2	CP-A3	CP-A4	CP-A5	CP-A6
6	GT-AE	OR	CP-A13	CP-A14	CP-A15			
7	GT-AD	OR	CP-A7	CP-A8	CP-A9	CP-A10	CP-A11	CP-A12
8	GT-AC	OR	CP-A1	CP-A2	CP-A3	CP-A4	CP-A5	CP-A6
9	GT-BA	OR	GT-BB	GT-BC				
10	GT-AB	OR	GT-AF	GT-AG	GT-AH			
11	GT-AA	OR	GT-AC	GT-AD	GT-AE			
12	GT-B	OR	GT-BA	CP-B1	CP-B2	CP-B3		
13	GT-A	AND	GT-AA	GT-AB				
14	TOP	OR	GT-A	GT-B				

Figure 8.4. (Continued)

```
*************************************************************************
TREBIL FAULT TREE BUILDING PROGRAM*
*************************************************************************
CSIS SAFTY ANALYSIS
```

TREE INDEX	COMPONENT NAME	NUMBER OF GATES INPUT	GATES INPUT	
1	CP-B4	1	GT-BC	
2	CP-B5	1	GT-BC	
3	CP-A13	2	GT-BB	GT-AE
4	CP-A16	2	GT-BB	GT-AH
5	CP-A14	2	GT-AH	GT-AE
6	CP-A15	2	GT-AH	GT-AE
7	CP-A7	2	GT-AG	GT-AD
8	CP-A8	2	GT-AG	GT-AD
9	CP-A9	2	GT-AG	GT-AD
10	CP-A10	2	GT-AG	GT-AD
11	CP-A11	2	GT-AG	GT-AD
12	CP-A12	2	GT-AG	GT-AD
13	CP-A1	2	GT-AF	GT-AC
14	CP-A2	2	GT-AF	GT-AC
15	CP-A3	2	GT-AF	GT-AC
16	CP-A4	2	GT-AF	GT-AC
17	CP-A5	2	GT-AF	GT-AC
18	CP-A6	2	GT-AF	GT-AC
19	CP-B1	1	GT-B	
20	CP-B2	1	GT-B	
21	CP-B3	1	GT-B	

Figure 8.4. (Continued)

LERs presented in Section 7.3. were used. These values are listed in Table 8.2. The fault tree shown in Fig. 8.3 was analyzed again using the PREP codes, and the results are shown in Fig. 8.5.

Table 8.2. Estimated values of the failure rates/error rates and the repair time/recovery time for the components in Fig. 8.3 using data extracted from LERs

Component symbol	Failure rates/ error rates (λ) (hours^{-1})	Repair time/ recovery time (hours)
CP-A1	0.198×10^{-6}	360
CP-A2	0.0003×10^{-6}	10
CP-A3	0.25×10^{-6}	360
CP-A4	0.298×10^{-6}	360
CP-A5	0.3×10^{-6}	360
CP-A6	0.8×10^{-6}	400
CP-A7	0.03×10^{-6}	360
CP-A8	30×10^{-6}	360
CP-A9	30×10^{-6}	360
CP-A10	30×10^{-6}	360
CP-A11	28×10^{-6}	300
CP-A12	0.03×10^{-6}	4400
CP-A13	0.75×10^{-6}	400
CP-A14	0.028×10^{-6}	360
CP-A15	3.05×10^{-6}	360
CP-A16	13.0×10^{-6}	360
CP-B1	0.0001×10^{-6}	24
CP-B2	0.0001×10^{-6}	24
CP-B3	0.0001×10^{-6}	4400
CP-B4	0.028×10^{-6}	360
CP-B5	0.028×10^{-6}	360

```
***********************************************************

***********************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
***********************************************************


CSIS SAFTY ANALYSIS

NUMBER OF GATES,NG-------------------------   14

COMBO STARTING VALUE,MIN-------------------    1

COMBO ENDING VALUE,MAX---------------------    5

CUT SET - PATH SET SWITCH,IDEX1------------    0

PRINT - PUNCH SWITCH,IDEX2-----------------    1

MONTE CARLO STARTER,MCS--------------------    0

NO. OF RANDOM NUMBERS TO REJECT,NREJEC-----    0

NO. OF MONTE CARLO TRIALS,NTR--------------    0

MIXING PARAMETER SWITCH,IREN---------------    0

MONTE CARLO MIXING PARAMETER,TAA-----------.0
```

Figure 8.5. Output of PREP computations

```
*****************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
*****************************************************************************


CSIS SAFTY ANALYSIS

NAME      TYPE      INPUTS----
TOP       OR    2 0 GT-A      GT-B
GT-A      AND   2 0 GT-AA     GT-AB
GT-B      OR    1 3 GT-BA     CP-B1     CP-B2     CP-B3
GT-AA     OR    3 0 GT-AC     GT-AD     GT-AE
GT-AB     OR    3 0 GT-AF     GT-AG     GT-AH
GT-AC     OR    0 6 CP-A1     CP-A2     CP-A3     CP-A4     CP-A5     CP-A6
GT-AD     OR    0 6 CP-A7     CP-A8     CP-A9     CP-A10    CP-A11    CP-A12
GT-AE     OR    0 3 CP-A13    CP-A14    CP-A15
GT-AF     OR    0 6 CP-A1     CP-A2     CP-A3     CP-A4     CP-A5     CP-A6
GT-AG     OR    0 6 CP-A7     CP-A8     CP-A9     CP-A10    CP-A11    CP-A12
GT-AH     OR    0 3 CP-A14    CP-A15    CP-A16
GT-BA     OR    2 0 GT-BB     GT-BC
GT-BB     AND   0 2 CP-A13    CP-A16
GT-BC     AND   0 2 CP-B4     CP-B5
END             0 0
```

Figure 8.5. (Continued)

```
******************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
******************************************************************


CSIS SAFTY ANALYSIS

          THIS IS THE SUBROUTINE GENERATED BY TREBIL
      SUBROUTINE TREE
      LOGICAL TOP,A( 500),X( 500)
      COMMON/TREES/A,X,TOP
      A(    1) = X(    1).AND.X(    2)
      A(    2) = X(    3).AND.X(    4)
      A(    3) = X(    5).OR.X(    6).OR.X(    4)
      A(    4) = X(    7).OR.X(    8).OR.X(    9).OR.X(   10)
     *          .OR.X(   11).OR.X(   12)
      A(    5) = X(   13).OR.X(   14).OR.X(   15).OR.X(   16)
     *          .OR.X(   17).OR.X(   18)
      A(    6) = X(    3).OR.X(    5).OR.X(    6)
      A(    7) = X(    7).OR.X(    8).OR.X(    9).OR.X(   10)
     *          .OR.X(   11).OR.X(   12)
      A(    8) = X(   13).OR.X(   14).OR.X(   15).OR.X(   16)
     *          .OR.X(   17).OR.X(   18)
      A(    9) = A(    2).OR.A(    1)
      A(   10) = A(    5).OR.A(    4).OR.A(    3)
      A(   11) = A(    8).OR.A(    7).OR.A(    6)
      A(   12) = A(    9)
     *          .OR.X(   19).OR.X(   20).OR.X(   21)
      A(   13) = A(   11).AND.A(   10)
      A(   14) = A(   13).OR.A(   12)
      TOP = A(   14)
      RETURN
      END
```

Figure 8.5. (Continued)

```
******************************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM                                                      *
******************************************************************************************
```

CSIS SAFTY ANALYSIS

COMPCNENT INDICES. NAMES. AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	CP-B4	2.80000D-08	3.60000D 02
2	CP-B5	2.80000D-08	3.60000D 02
3	CP-A13	7.50000D-07	4.00000D 02
4	CP-A16	1.30000D-05	3.60000D 02
5	CP-A14	2.80000D-08	3.60000D 02
6	CP-A15	3.05000D-06	3.60000D 02
7	CP-A7	3.00000D-08	3.60000D 02
8	CP-A8	3.00000D-05	3.60000D 02
9	CP-A9	3.00000D-05	3.60000D 02
10	CP-A10	3.00000D-05	5.00000D-01
11	CP-A11	2.80000D-05	3.00000D 02
12	CP-A12	3.00000D-08	4.40000D 03
13	CP-A1	1.98000D-07	3.60000D 02
14	CP-A2	3.00000D-10	1.00000D 01
15	CP-A3	2.50000D-07	3.60000D 02
16	CP-A4	2.98000D-07	3.60000D 02
17	CP-A5	3.00000D-07	4.00000D 02
18	CP-A6	8.00000D-07	4.00000D 02
19	CP-B1	1.00000D-10	2.40000D 01
20	CP-B2	1.00000D-10	2.40000D 01
21	CP-B3	1.00000D-10	4.40000D 03

Figure 8.5. (Continued)

```
******************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM                                          *
******************************************************************************
```

CSIS SAFTY ANALYSIS

TREE INDEX	GATE NAME		INPUTS--					
1	GT-BC	AND	CP-B4	CP-B5				
2	GT-BB	AND	CP-A13	CP-A16				
3	GT-AH	OR	CP-A14	CP-A15	CP-A16			
4	GT-AG	OR	CP-A7	CP-A8	CP-A9	CP-A10	CP-A11	CP-A12
5	GT-AF	OR	CP-A1	CP-A2	CP-A3	CP-A4	CP-A5	CP-A6
6	GT-AE	OR	CP-A13	CP-A14	CP-A15			
7	GT-AD	OR	CP-A7	CP-A8	CP-A9	CP-A10	CP-A11	CP-A12
8	GT-AC	OR	CP-A1	CP-A2	CP-A3	CP-A4	CP-A5	CP-A6
9	GT-BA	OR	GT-BB	GT-BC				
10	GT-AB	OR	GT-AF	GT-AG	GT-AH			
11	GT-AA	OR	GT-AC	GT-AD	GT-AE			
12	GT-B	OR	GT-BA	CP-B1	CP-B2	CP-B3		
13	GT-A	AND	GT-AA	GT-AB				
14	TOP	OR	GT-A	GT-B				

Figure 8.5. (Continued)

```
************************************************************
TREBIL FAULT TREE BUILDING PROGRAM*
************************************************************
CSIS SAFTY ANALYSIS
```

TREE INDEX	COMPONENT NAME	NUMBER OF GATES INPUT	GATES INPUT	
1	CP-B4	1	GT-BC	
2	CP-B5	1	GT-BC	
3	CP-A13	2	GT-BB	GT-AE
4	CP-A16	2	GT-BB	GT-AH
5	CP-A14	2	GT-AH	GT-AE
6	CP-A15	2	GT-AH	GT-AE
7	CP-A7	2	GT-AG	GT-AD
8	CP-A8	2	GT-AG	GT-AD
9	CP-A9	2	GT-AG	GT-AD
10	CP-A10	2	GT-AG	GT-AD
11	CP-A11	2	GT-AG	GT-AD
12	CP-A12	2	GT-AG	GT-AD
13	CP-A1	2	GT-AF	GT-AC
14	CP-A2	2	GT-AF	GT-AC
15	CP-A3	2	GT-AF	GT-AC
16	CP-A4	2	GT-AF	GT-AC
17	CP-A5	2	GT-AF	GT-AC
18	CP-A6	2	GT-AF	GT-AC
19	CP-B1	1	GT-B	
20	CP-B2	1	GT-B	
21	CP-B3	1	GT-B	

Figure 8.5. (Continued)

In the third case, WASH-1400 data were used to estimate the values of the failure rate λ and the repair time τ. For human events (CP-A1 and CP-A4), the calculated human error rates using NUREG/CR-1278 presented in Section 7.4 were used. These values are listed in Table 8.3. The fault tree shown in Fig. 8.3 was analyzed again using the PREP codes, and the results are shown in Fig. 8.6.

In the fourth case, WASH-1400 (1) and the LERs (Section 7) were used to estimate the values of the failure (human) rate λ and repair time τ. In this case, sensitivity analysis was performed. The reason for doing this is to point out the sensitivity of the CSIS reliability performance to human errors. By examining the fault tree presented in Fig. 8.2, two human-related events were found. Those events are represented by CP-A1 and CP-A4 in the fault tree. The sensitivity analysis was performed by following these steps:

(a) Keeping CP-A1 constant and slightly varying CP-A4. This variation is presented in Table 8.4.

(b) Keeping CP-A4 constant and slightly varying CP-A1. This variation is illustrated in Table 8.5.

The fault tree shown in Fig. 8.3 was analyzed for each point; i.e., seven times for each step using the PREP

Table 8.3. Estimated values of the failure rates/error rates and the repair time/recovery time for the components in Fig. 8.3 using data from NUREG/CR-1278

Component symbol	Failure rates/ error rates (λ) (hours^{-1})	Repair time/ recovery time (hours)
CP-A1	6.25×10^{-6}	360
CP-A2	0.0003×10^{-6}	10
CP-A3	0.25×10^{-6}	360
CP-A4	6.25×10^{-6}	360
CP-A5	0.3×10^{-6}	360
CP-A6	0.8×10^{-6}	400
CP-A7	0.03×10^{-6}	360
CP-A8	30×10^{-6}	360
CP-A9	30×10^{-6}	360
CP-A10	30×10^{-6}	360
CP-A11	28×10^{-6}	300
CP-A12	0.03×10^{-6}	4400
CP-A13	6.75×10^{-6}	400
CP-A14	0.028×10^{-6}	360
CP-A15	3.05×10^{-6}	360
CP-A16	13.0×10^{-6}	360
CP-B1	0.0001×10^{-6}	24
CP-B2	0.0001×10^{-6}	24
CP-B3	0.0001×10^{-6}	4400
CP-B4	0.028×10^{-6}	360
CP-B5	0.028×10^{-6}	360

```
*********************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
*********************************************************


CSIS SAFTY ANALYSIS

NUMBER OF GATES,NG-------------------------    14

COMBO STARTING VALUE,MIN-------------------     1

COMBO ENDING VALUE,MAX---------------------     5

CUT SET - PATH SET SWITCH,IDEX1------------     0

PRINT - PUNCH SWITCH,IDEX2-----------------     1

MONTE CARLO STARTER,MCS--------------------     0

NO. OF RANDOM NUMBERS TO REJECT,NREJEC-----     0

NO. OF MONTE CARLO TRIALS,NTR--------------     0

MIXING PARAMETER SWITCH,IREN---------------     0

MONTE CARLO MIXING PARAMETER,TAA-----------.0
```

Figure 8.6. Output of PREP computations

```
*************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
*************************************************************************


CSIS SAFTY ANALYSIS

NAME     TYPE     INPUTS----
TOP      OR    2 0 GT-A      GT-B
GT-A     AND   2 0 GT-AA     GT-AB
GT-B     OR    1 3 GT-BA     CP-B1     CP-B2     CP-B3
GT-AA    OR    3 0 GT-AC     GT-AD     GT-AE
GT-AB    OR    3 0 GT-AF     GT-AG     GT-AH
GT-AC    OR    0 6 CP-A1     CP-A2     CP-A3     CP-A4     CP-A5     CP-A6
GT-AD    OR    0 6 CP-A7     CP-A8     CP-A9     CP-A10    CP-A11    CP-A12
GT-AE    OR    0 3 CP-A13    CP-A14    CP-A15
GT-AF    OR    0 6 CP-A1     CP-A2     CP-A3     CP-A4     CP-A5     CP-A6
GT-AG    OR    0 6 CP-A7     CP-A8     CP-A9     CP-A10    CP-A11    CP-A12
GT-AH    OR    0 3 CP-A14    CP-A15    CP-A16
GT-BA    OR    2 0 GT-BB     GT-BC
GT-BB    AND   0 2 CP-A13    CP-A16
GT-BC    AND   0 2 CP-B4     CP-B5
END            0 0
```

Figure 8.6. (Continued)

```
**********************************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM                                                         *
**********************************************************************************************
```

CSIS SAFTY ANALYSIS

COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	CP-B4	2.80000D-08	3.60000D 02
2	CP-B5	2.80000D-08	3.60000D 02
3	CP-A13	7.50000D-07	4.00000D 02
4	CP-A16	1.30000D-05	3.60000D 02
5	CP-A14	2.80000D-08	3.60000D 02
6	CP-A15	3.05000D-06	3.60000D 02
7	CP-A7	3.00000D-08	3.60000D 02
8	CP-A8	3.00000D-05	3.60000D 02
9	CP-A9	3.00000D-05	3.60000D 02
10	CP-A10	3.00000D-05	5.00000D-01
11	CP-A11	2.80000D-05	3.00000D 02
12	CP-A12	3.00000D-08	4.40000D 03
13	CP-A1	6.25000D-06	3.60000D 02
14	CP-A2	3.00000D-10	1.00000D 01
15	CP-A3	2.50000D-07	3.60000D 02
16	CP-A4	6.25000D-06	3.60000D 02
17	CP-A5	3.00000D-07	4.00000D 02
18	CP-A6	8.00000D-07	4.00000D 02
19	CP-B1	1.00000D-10	2.40000D 01
20	CP-B2	1.00000D-10	2.40000D 01
21	CP-B3	1.00000D-10	4.40000D 03

Figure 8.6. (Continued)

```
*****************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
*****************************************************************************


CSIS SAFTY ANALYSIS

          THIS IS THE SUBROUTINE GENERATED BY TREBIL
      SUBROUTINE TREE
      LOGICAL TOP,A( 500),X( 500)
      COMMON/TREES/A,X,TOP
      A(    1) = X(    1).AND.X(    2)
      A(    2) = X(    3).AND.X(    4)
      A(    3) = X(    5).OR.X(    6).OR.X(    4)
      A(    4) = X(    7).OR.X(    8).OR.X(    9).OR.X(   10)
     *          .OR.X(   11).OR.X(   12)
      A(    5) = X(   13).OR.X(   14).OR.X(   15).OR.X(   16)
     *          .OR.X(   17).OR.X(   18)
      A(    6) = X(    3).OR.X(    5).OR.X(    6)
      A(    7) = X(    7).OR.X(    8).OR.X(    9).OR.X(   10)
     *          .OR.X(   11).OR.X(   12)
      A(    8) = X(   13).OR.X(   14).OR.X(   15).OR.X(   16)
     *          .OR.X(   17).OR.X(   18)
      A(    9) = A(    2).OR.A(    1)
      A(   10) = A(    5).OR.A(    4).OR.A(    3)
      A(   11) = A(    8).OR.A(    7).OR.A(    6)
      A(   12) = A(    9)
     *          .OR.X(   19).OR.X(   20).OR.X(   21)
      A(   13) = A(   11).AND.A(   10)
      A(   14) = A(   13).OR.A(   12)
      TOP = A(   14)
      RETURN
      END
```


Figure 8.6. (Continued)

```
*************************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
*************************************************************************************
```

CSIS SAFTY ANALYSIS

TREE INDEX	GATE NAME		INPUTS--					
1	GT-BC	AND	CP-B4	CP-B5				
2	GT-BB	AND	CP-A13	CP-A16				
3	GT-AH	OR	CP-A14	CP-A15	CP-A16			
4	GT-AG	OR	CP-A7	CP-A8	CP-A9	CP-A10	CP-A11	CP-A12
5	GT-AF	OR	CP-A1	CP-A2	CP-A3	CP-A4	CP-A5	CP-A6
6	GT-AE	OR	CP-A13	CP-A14	CP-A15			
7	GT-AD	OR	CP-A7	CP-A8	CP-A9	CP-A10	CP-A11	CP-A12
8	GT-AC	OR	CP-A1	CP-A2	CP-A3	CP-A4	CP-A5	CP-A6
9	GT-BA	OR	GT-BB	GT-BC				
10	GT-AB	OR	GT-AF	GT-AG	GT-AH			
11	GT-AA	OR	GT-AC	GT-AD	GT-AE			
12	GT-B	OR	GT-BA	CP-B1	CP-B2	CP-B3		
13	GT-A	AND	GT-AA	GT-AB				
14	TOP	OR	GT-A	GT-B				

Figure 8.6. (Continued)

****
TREBIL FAULT TREE BUILDING PROGRAM*
****
CSIS SAFTY ANALYSIS

TREE INDEX	COMPONENT NAME	NUMBER OF GATES INPUT	GATES INPUT	
1	CP-B4	1	GT-BC	
2	CP-B5	1	GT-BC	
3	CP-A13	2	GT-BB	GT-AE
4	CP-A16	2	GT-BB	GT-AH
5	CP-A14	2	GT-AH	GT-AE
6	CP-A15	2	GT-AH	GT-AE
7	CP-A7	2	GT-AG	GT-AD
8	CP-A8	2	GT-AG	GT-AD
9	CP-A9	2	GT-AG	GT-AD
10	CP-AI0	2	GT-AG	GT-AD
11	CP-A11	2	GT-AG	GT-AD
12	CP-A12	2	GT-AG	GT-AD
13	CP-A1	2	GT-AF	GT-AC
14	CP-A2	2	GT-AF	GT-AC
15	CP-A3	2	GT-AF	GT-AC
16	CP-A4	2	GT-AF	GT-AC
17	CP-A5	2	GT-AF	GT-AC
18	CP-A6	2	GT-AF	GT-AC
19	CP-B1	1	GT-B	
20	CP-B2	1	GT-B	
21	CP-B3	1	GT-B	

Figure 8.6. (Continued)

Table 8.4. Constant human error rates for a constant value of CP-Al and different values for CP-A4

CP-A4 x 10^{-6}	0.001	0.01	1.0	10	100	1000
CP-Al x 10^{-6}	0.198	0.198	0.198	0.198	0.198	0.198

codes. In this case, the results from PREP are not shown because the results are similar to cases 1 and 2.

Table 8.5. Constant human error rates for a constant value of CP-A4 and different values for CP-Al

CP-Al x 10^{-6}	0.001	0.01	1.0	10	100	1000
CP-A4 x 10^{-6}	0.298	0.298	0.298	0.298	0.298	0.298

8.4. KITT-1 Results for the CSIS Fault Tree

8.4.1. Case 1: WASH-1400

Having obtained the minimal cut sets from the PREPS, the KITT-1 code was then run to obtain the probability characteristics associated with insufficient fluid flow to the CSIS fault tree. The results from the KITT-1 code include insufficient fluid flow to the CSIS system, differential and integral characteristics, the inhibit characteristics of every component, and the minimal cut sets characteristics. The terms and the results from KITT-1 are shown in Appendix

E. Some of the component inhibit characteristics resulting from the KITT-1 codes run are summarized in Table 8.6.

Table 8.6. Some CSIS component characteristics resulted from KITT-1 code run using data from WASH-1400 at operation time of 50 hours

Component or event	Unavailability (Q) (per hour)	Probability of one or more failures to time t (FSUM)
1	1.01×10^{-5}	1.11×10^{-5}
3	3.0×10^{-4}	3.37×10^{-4}
4	4.67×10^{-3}	5.18×10^{-3}
6	1.09×10^{-3}	1.21×10^{-3}
8	1.07×10^{-2}	1.19×10^{-2}
10	1.5×10^{-5}	1.19×10^{-2}
11	8.34×10^{-3}	1.11×10^{-2}
13	3.6×10^{-7}	4.5×10^{-7}
14	3.0×10^{-9}	1.2×10^{-7}
16	1.07×10^{-5}	1.19×10^{-5}
17	1.19×10^{-4}	1.35×10^{-4}
20	2.4×10^{-9}	4.0×10^{-8}

The program output symbols are defined as follows:

T = t, time (in hours);

Q = $\underline{q}(t)$, the component failed probability;

W = w(t), the component failure rate (per hour);

L = the (input) component failure intensity (per hour);

WSUM = the expected number of failure to time t; and

FSUM = the probability of one or more failures to time t.

The characteristics of some of the minimal cut sets obtained from the KITT-1 codes run are summarized in Table 8.7 where the program output symbols are defined as follows:

T = t, time (in hours);

Q = $\underset{\sim}{q}$(t), the minimal cut set failed probability;

W = w(t), the minimal cut set failure rate (per hour); and

L = A(t), the minimal cut set failure intensity (per hour).

Table 8.7. Some CSIS minimal cut set characteristics resulted from KITT-1 code run using data from WASH-1400 at operation time of 50 hours

Minimal cut set	Unavailability (Q) (per hour)	Probability of one or more failure to time t (FSUM)
1	1.01×10^{-5}	1.12×10^{-5}
2	1.09×10^{-3}	1.22×10^{-3}
4	1.07×10^{-2}	1.19×10^{-2}
6	1.5×10^{-5}	1.19×10^{-2}
7	8.35×10^{-3}	1.11×10^{-2}
9	3.6×10^{-7}	4.0×10^{-7}
10	3.0×10^{-9}	1.12×10^{-7}
11	8.99×10^{-5}	1.00×10^{-4}
14	3.12×10^{-4}	3.6×10^{-4}
16	2.4×10^{-9}	4.0×10^{-8}
18	1.01×10^{-10}	1.23×10^{-10}
19	1.4×10^{-6}	1.54×10^{-6}

Some of the system differential and integral characteristics resulted from the KITT-1 codes run are summarized in Table 8.8 and plotted in Figs. 8.7 and 8.8 where the

Table 8.8. CSIS differential characteristics resulting from KITT-1 code run using data from WASH-1400

T(hours)	Unavailability (Q) (per demand)	Probability of one or more failure to time t (FSUM)
0.0	0.0	--
50.0	6.26×10^{-2}	7.76×10^{-2}
100.0	1.25×10^{-1}	1.55×10^{-1}
150.0	1.86×10^{-1}	2.32×10^{-1}
200.0	2.48×10^{-1}	3.09×10^{-1}
250.0	3.09×10^{-1}	3.86×10^{-1}
300.0	3.69×10^{-1}	4.63×10^{-1}
350.0	4.16×10^{-1}	5.39×10^{-1}
400.0	4.26×10^{-1}	6.15×10^{-1}
500.0	4.25×10^{-1}	7.65×10^{-1}
600.0	4.24×10^{-1}	9.13×10^{-1}
700.0	4.24×10^{-1}	1.06×10^{-1}
750.0	4.24×10^{-1}	1.13×10^{0}
800.0	4.24×10^{-1}	1.20×10^{0}
850.0	4.24×10^{-1}	1.27×10^{0}
900.0	4.24×10^{-1}	1.34×10^{0}
950.0	4.24×10^{-1}	1.41×10^{0}

program output symbols are defined as follows (60):

T = t, time (in hours);

Q = the upper bound for $Q_0(1)$ where $Q_0(1)$ is the probability that the system is in its failed state at time t;

W = the upper bound for $W_0(t)$ (per hour) where $W_0(t)$ is the expected number of failures the system will

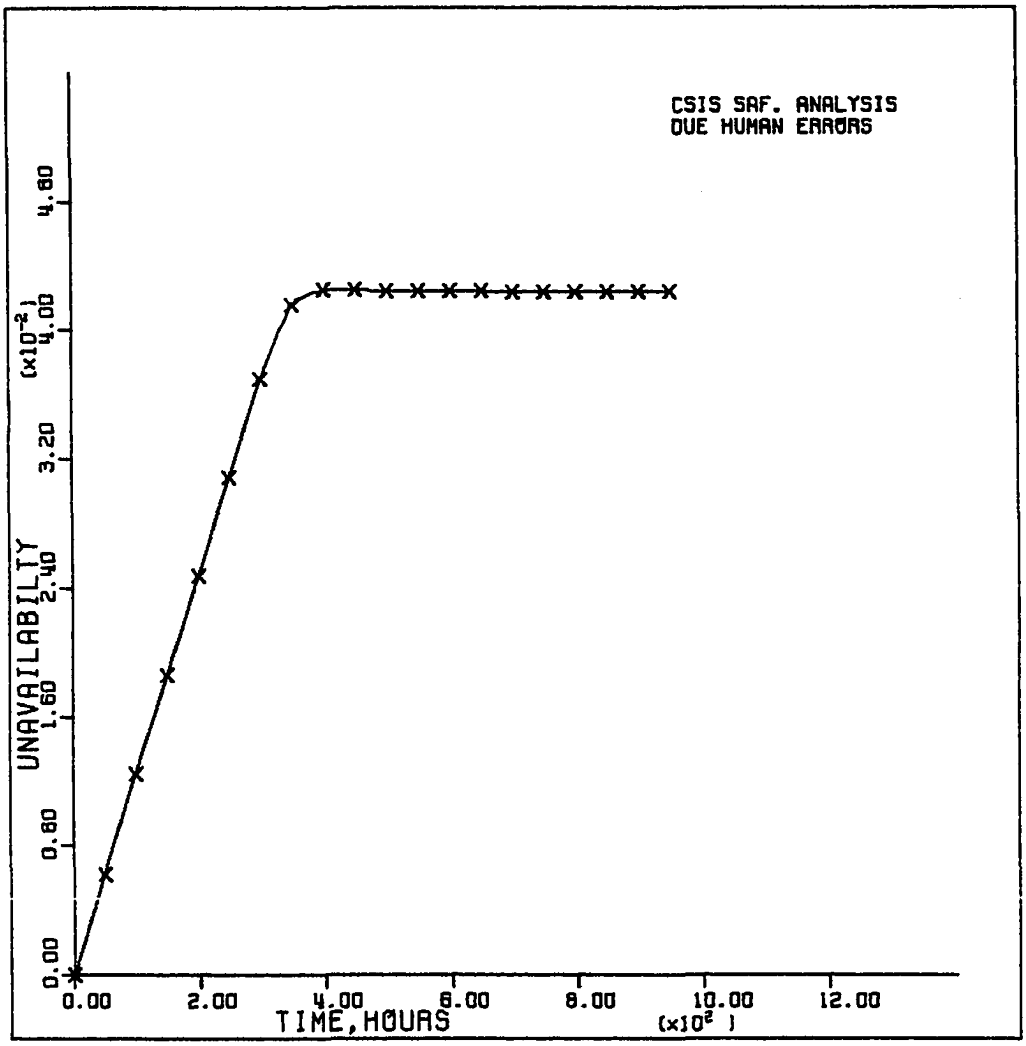

Figure 8.7. CSIS unavailability based on data from WASH-1400

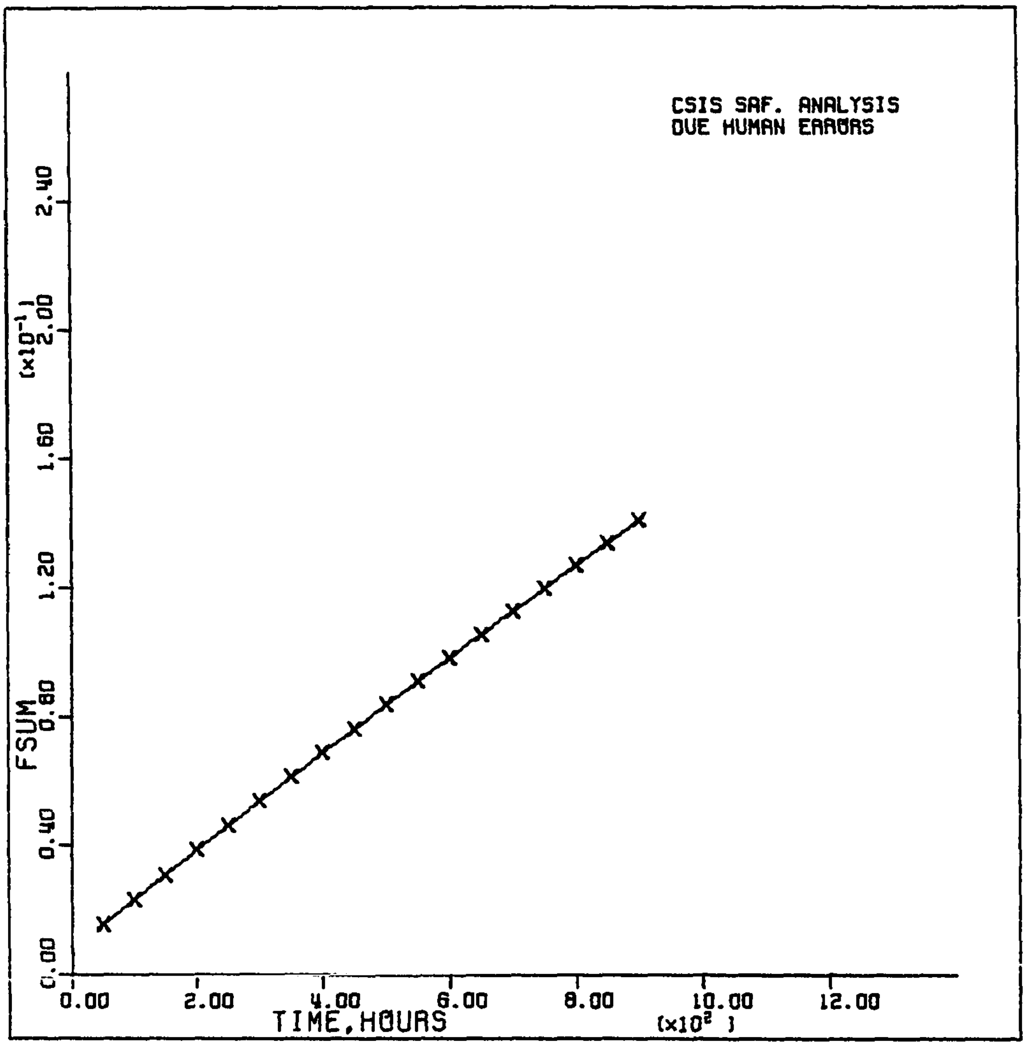

Figure 8.8. The probability of one or more failures to time t for the CSIS based on data from WASH-1400

suffer per unit time at time t;

L = the upper bound for $A_0(t)$ (per hour) where $A_0(t)$ is the probability that the system will suffer a failure per unit time at time t given it is in its functioning state at time t;

WSUM = the upper bound for $\int_0^t W_0(t')dt'$ where $\int_0^t W_0(t')dt'$ is the expected number of failures the system will suffer during the time interval from 0 to t;

FSUM = the upper bound for $1 -[\exp -\int_0^t \Lambda_0(t')dt']$ where $1 - \exp[-\int_0^t \Lambda_0(t')dt']$ is 0 the probability that the system will suffer one or more failures in the time interval from 0 to t.

8.4.2. Case 2: LERs

Having obtained the minimal cut sets from the PREPS, KITT-1 was then run to obtain the probability characteristics associated with insufficient fluid flow to the CSIS fault tree. The results from KITT-1 are shown in Appendix E.

Some of the components and system differential and integral characteristics resulting from the KITT-1 code run are summarized below in Tables 8.9 and 8.10 and plotted in Figs. 8.9 and 8.10 where the program output symbols are defined as follows (60):

T = t, time (in hours);

Table 8.9. Some CSIS component characteristics resulting from KITT-1 code run using data from LERs at operation time t of 50 hours

Component or event	Unavailability (Q) (per hour)	Probability of one or more failure to time t (FSUM)
1	1.01×10^{-5}	2.66×10^{-5}
3	2.99×10^{-5}	7.12×10^{-4}
4	4.66×10^{-3}	1.23×10^{-2}
6	1.1×10^{-3}	2.89×10^{-3}
8	1.07×10^{-2}	2.81×10^{-2}
10	1.5×10^{-4}	2.81×10^{-2}
11	8.33×10^{-3}	2.63×10^{-2}
13	7.13×10^{-5}	1.88×10^{-4}
14	3.00×10^{-9}	2.85×10^{-7}
16	1.07×10^{-4}	2.83×10^{-4}
17	1.2×10^{-4}	2.85×10^{-4}

Table 8.10. Some CSIS system characteristics resulting from KITT-code run using data extracted from LERs

T(hours)	Unavailability (Q) (per demand)	Probability of one or more failure to time t (FSUM)
0.0	0.0	--
50.0	4.65×10^{-2}	6.14×10^{-2}
100.0	9.26×10^{-2}	1.23×10^{-1}
150.0	1.38×10^{-1}	1.84×10^{-1}
200.0	1.84×10^{-1}	2.45×10^{-1}
250.0	2.29×10^{-1}	3.05×10^{-1}
300.0	2.75×10^{-1}	3.66×10^{-1}
350.0	3.06×10^{-1}	4.26×10^{-1}
400.0	3.12×10^{-1}	4.87×10^{-1}
450.0	3.12×10^{-1}	5.46×10^{-1}
500.0	3.12×10^{-1}	6.06×10^{-1}
550.0	3.12×10^{-1}	6.65×10^{-1}
600.0	3.12×10^{-1}	7.24×10^{-1}
650.0	3.12×10^{-1}	7.82×10^{-1}
700.0	3.12×10^{-1}	8.39×10^{-1}
750.0	3.12×10^{-1}	8.97×10^{-1}
800.0	3.12×10^{-1}	9.55×10^{-1}
850.0	3.12×10^{-1}	1.01×10^{0}
900.0	3.12×10^{-1}	1.07×10^{0}
950.0	3.12×10^{-1}	1.12×10^{0}

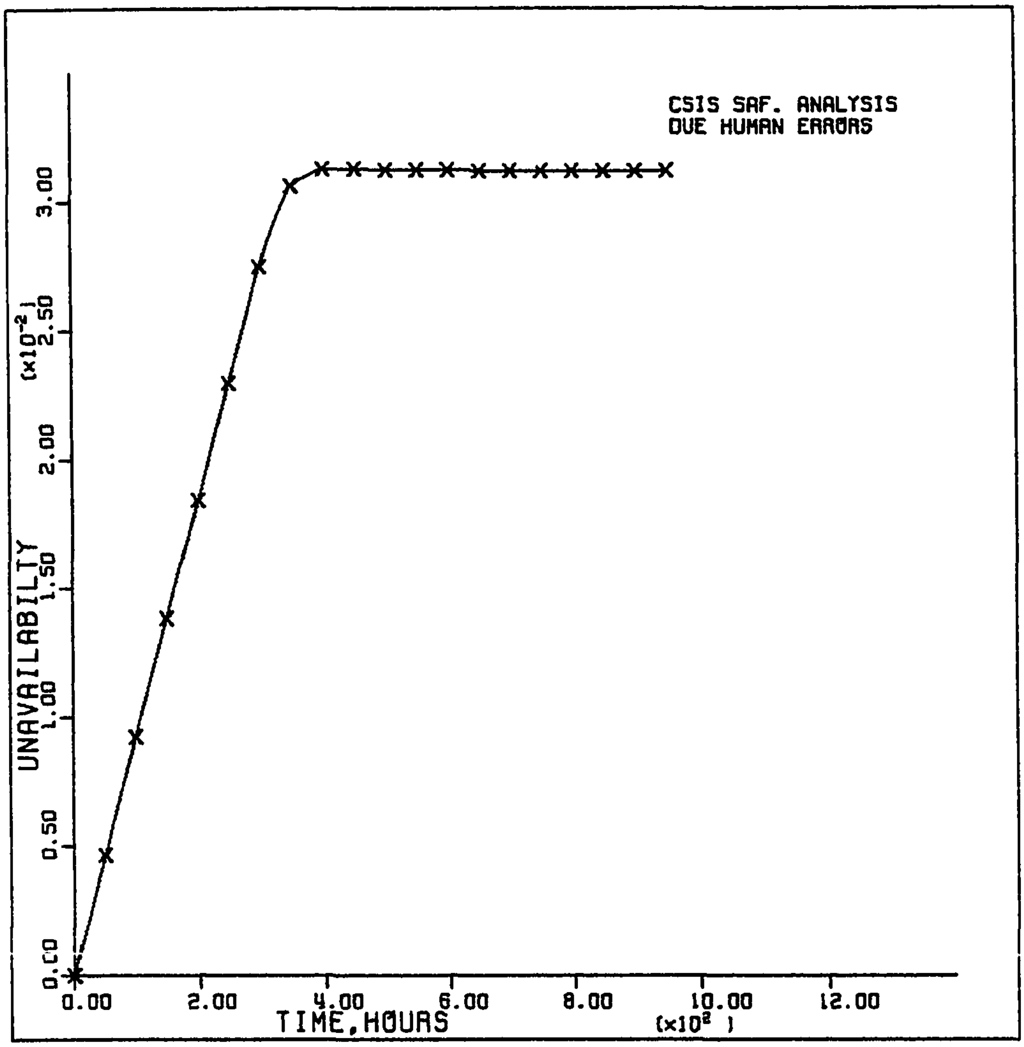

Figure 8.9. CSIS unavailability based on data extracted from LERs

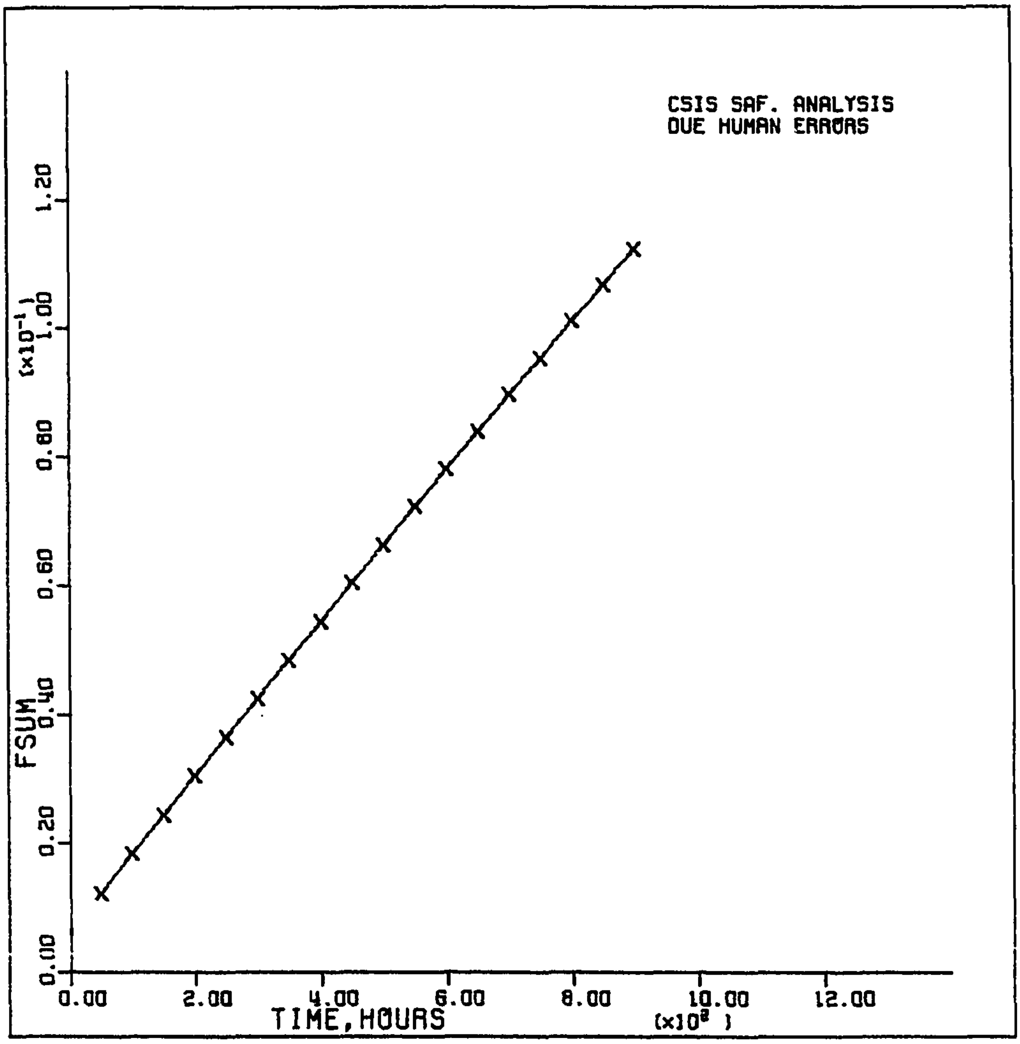

Figure 8.10. Probability of one or more failures to time t for CSIS based on data extracted from LERs

Q = the upper bound for $Q_0(1)$[1];

W = the upper bound for $W_0(t)$[1] (per hour);

L = the upper bound for $\Lambda_0(t)$[1] (pher hour);

WSUM = the upper bound for

$$-\int_0^t W_0(t')\ dt'^{1}\ ;$$

FSUM = the upper bound for

$$1 - \exp[-\int_0^t \Lambda_0(t')\ dt']^{1}\ ;$$

8.4.3. Case 3: NUREG/CR-1278

Having obtained the minimal cut sets from the PREPS, KITT-1 was then run to obtain the probability characteristics associated with insufficient fluid flow to the CSIS fault tree. The results from KITT-1 are shown in Appendix E.

Some of the system differential and integral characteristics resulting from the KITT-1 code run are summarized below in Table 8.11 and plotted in Figs. 8.11 and 8.12, where the program output symbols are defined as follows (60):

T = t, time (in hours);

Q = the upper bound for $Q_0(1)$[1];

W = the upper bound for $W_0(t)$[1] (per hour);

L = the upper bound for $\Lambda_0(t)$[1] per hour);

WSUM = the upper bound for

$$\int_0^t W_0(t')\ dt'^{1}\ ;$$

---

[1]Definition of these terms is given in Section 8.4.1.

Table 8.11. Some CSIS system characteristics resulting from KITT-1 code run using data extracted from NUREG/CR-1278

T(hours)	Unavailability (Q) (per demand)	Probability of one or more failure to time t (FSUM)
0.0	0.0	--
50.0	5.24×10^{-3}	6.74×10^{-3}
100.0	1.04×10^{-2}	1.34×10^{-2}
150.0	1.56×10^{-2}	2.01×10^{-2}
200.0	2.07×10^{-2}	2.68×10^{-2}
250.0	2.59×10^{-2}	3.35×10^{-2}
300.0	3.10×10^{-2}	4.01×10^{-2}
350.0	3.47×10^{-2}	4.68×10^{-2}
400.0	3.54×10^{-2}	5.34×10^{-2}
450.0	3.54×10^{-2}	5.99×10^{-2}
500.0	3.54×10^{-2}	6.64×10^{-2}
550.0	3.54×10^{-2}	7.29×10^{-2}
600.0	3.54×10^{-2}	7.93×10^{-2}
650.0	3.54×10^{-2}	8.57×10^{-2}
700.0	3.53×10^{-2}	9.20×10^{-2}
750.0	3.53×10^{-2}	9.83×10^{-2}
800.0	3.53×10^{-2}	1.04×10^{-1}
850.0	3.53×10^{-2}	1.11×10^{-1}
900.0	3.53×10^{-2}	1.17×10^{-1}
950.0	3.53×10^{-2}	1.23×10^{-1}

FSUM = the upper bound for

$$1 - \exp\left[- \int_0^t \Lambda_0(t')dt'\right]^{1} .$$

[1]Definition of these terms is given in Section 8.4.1.

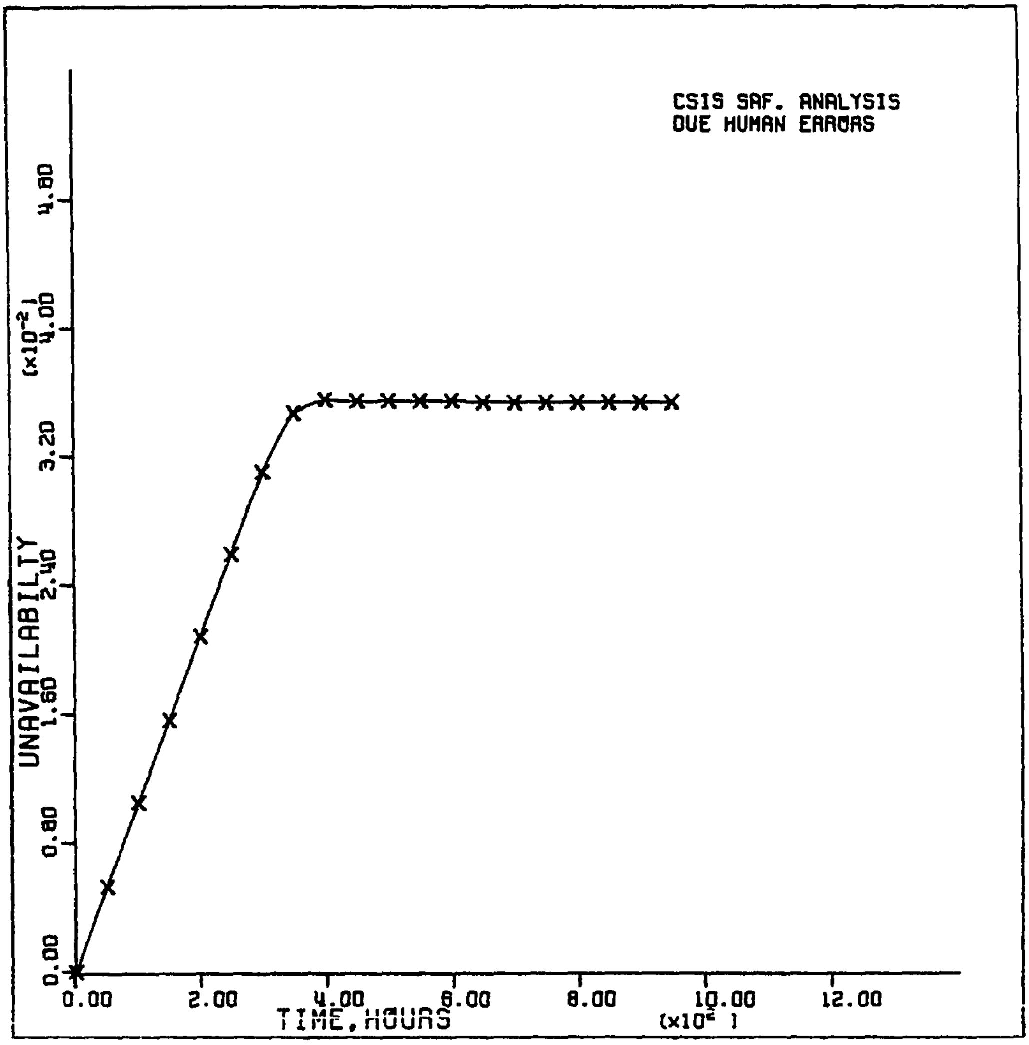

Figure 8.11. CSIS unavailability based on data extracted from NUREG/CR-1278

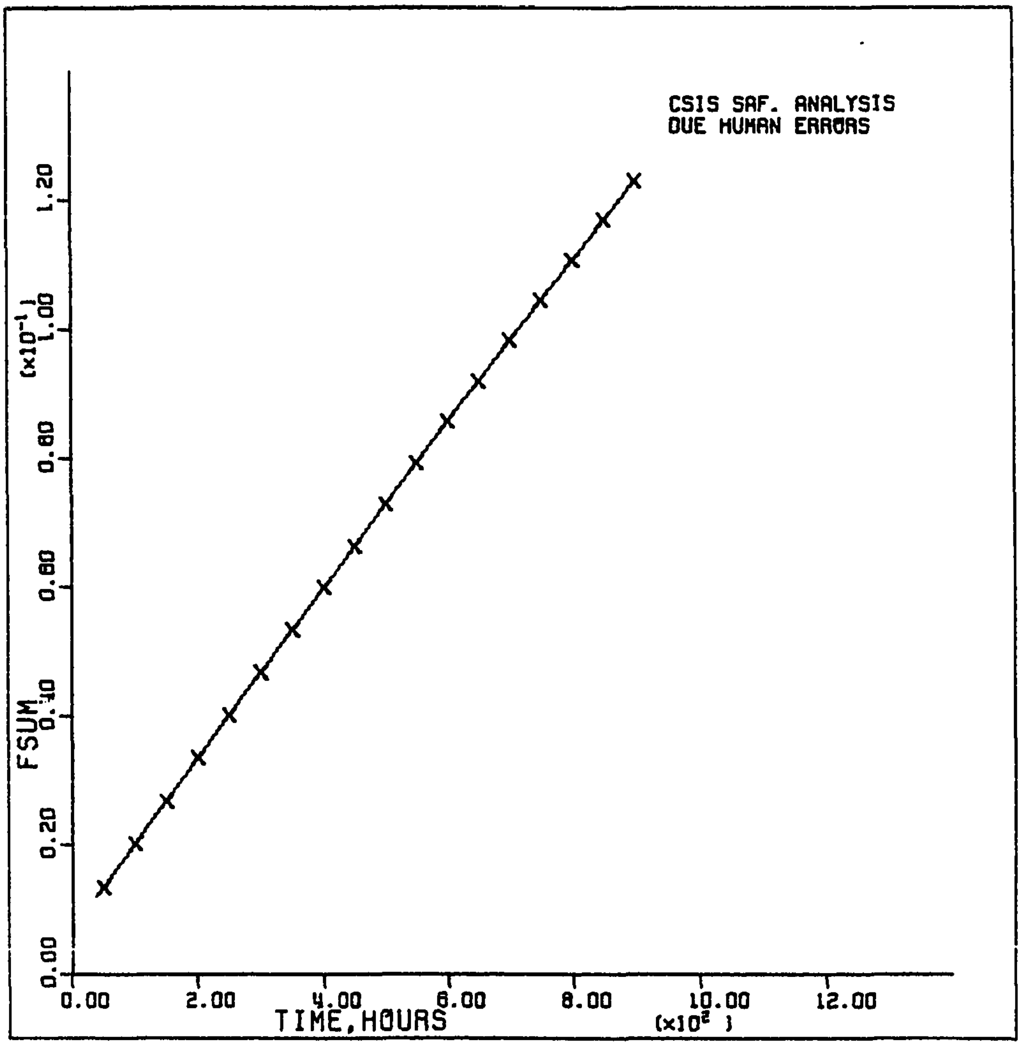

Figure 8.12. Probability of one or more failures to time t for CSIS based on data extracted from NUREG/ CR-1278

8.4.4. Case 4: Sensitivity of CSIS reliability to human errors

As was mentioned earlier in Section 8.3.3 (the fourth case), two steps were described for performing the CSIS sensitivity analysis. These two steps are:

(a) Keeping the human error rate for CP-A1 constant and varying it for CP-A4. The PREP codes were then run for each point.

(b) Keeping human error rate for CP-A4 constant and varying it for CP-A1. The PREP codes were then run for each point.

Having obtained the minimal cut sets from the PREPs, KITT-1 was then run seven times to obtain the probability characteristics associated with insufficient fluid to the CSIS fault tree. The whole results from KITT-1 are not shown because they are similar to the other cases.

Some of the system differential and integral characteristics resulting from each KITT-1 code run are presented in Table 8.12a for step (a) and in Table 8.12b for step (b) and plotted in Figs. 8.13 through 8.16 where the program output symbols are defined as follow:

λ = human error rate (hr^{-1});

Q = the upper bound for $Q_0(t)$[1];

FSUM = the upper bound for

$$1 - \exp\left[- \int_0^t \Lambda\ (t')\ dt'\right]^1 .$$

---

[1]Definition of these terms is given in Section 8.4.1.

Table 8.12a. Some CSIS characteristics resulting from KITT-1 code runs for step (a) at time t (t = 0, to 50 hours)

Human error rate for CP-A4 (hr^{-1})	Unavailability (Q) (per demand)	Probability of one or more failure to time t (FSUM)
10^{-9}	4.63×10^{-3}	6.126×10^{-3}
10^{-8}	4.631×10^{-3}	6.127×10^{-3}
10^{-7}	4.636×10^{-3}	6.132×10^{-3}
10^{-6}	4.681×10^{-3}	6.176×10^{-3}
10^{-5}	5.127×10^{-3}	6.627×10^{-3}
10^{-4}	9.563×10^{-3}	1.111×10^{-2}
10^{-3}	5.018×10^{-2}	5.485×10^{-2}

Table 8.12b. Some CSIS characteristics resulting from KITT-1 code runs for step (b) at time t (t = 0, to 50 hours)

Human error rate for CP-A1 (hr^{-1})	Unavailability (Q) (per demand)	Probability of one or more failure to time t (FSUM)
10^{-9}	4.636×10^{-3}	6.131×10^{-3}
10^{-8}	4.637×10^{-3}	6.132×10^{-3}
10^{-7}	4.641×10^{-3}	6.136×10^{-3}
10^{-6}	4.685×10^{-3}	6.182×10^{-3}
10^{-5}	5.133×10^{-3}	6.631×10^{-3}
10^{-4}	9.568×10^{-3}	1.111×10^{-2}
10^{-3}	5.018×10^{-2}	5.485×10^{-2}

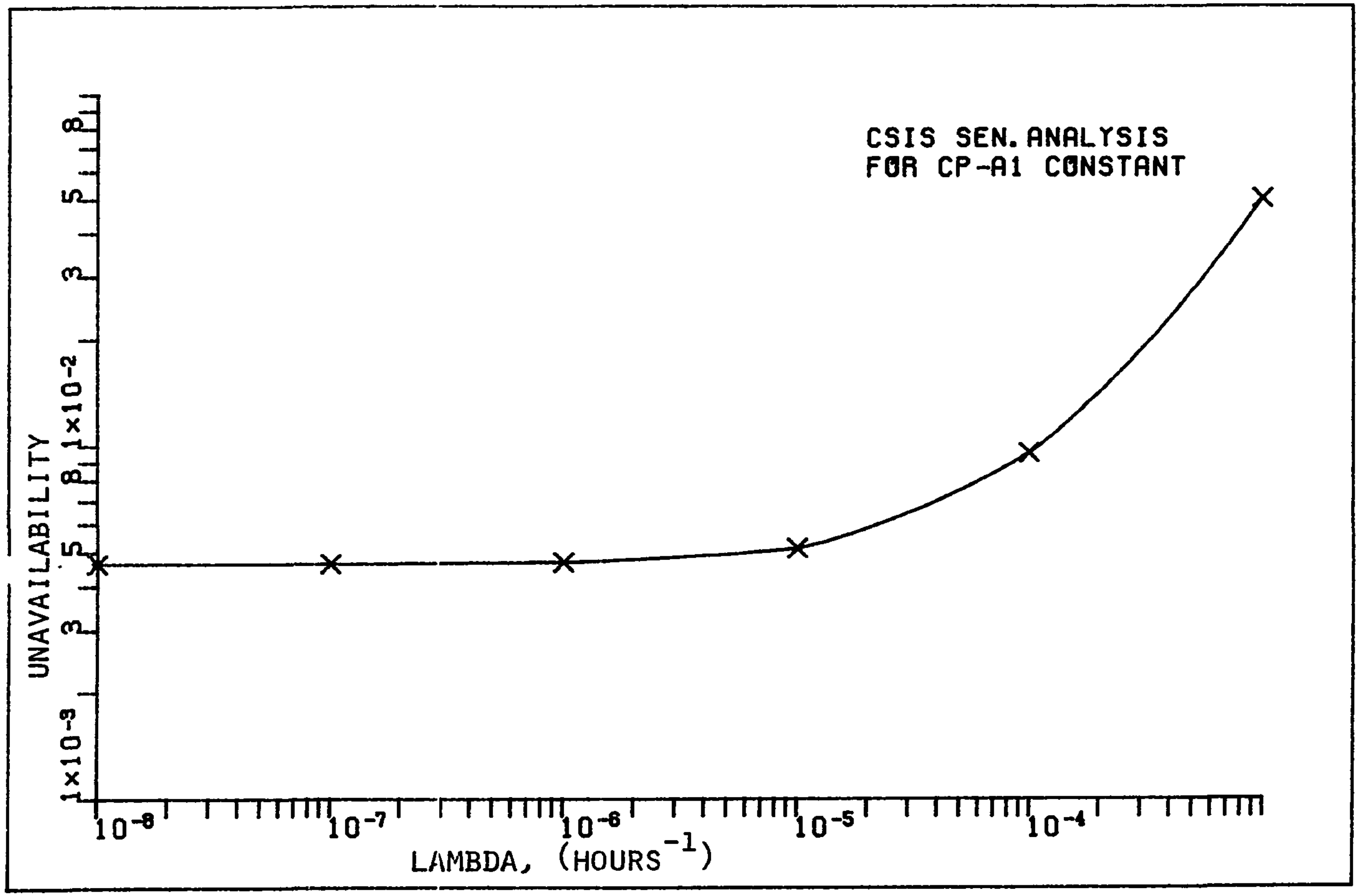

Figure 8.13. Unavailability for CSIS as a function of operator error rates at time 0 to 50 hours

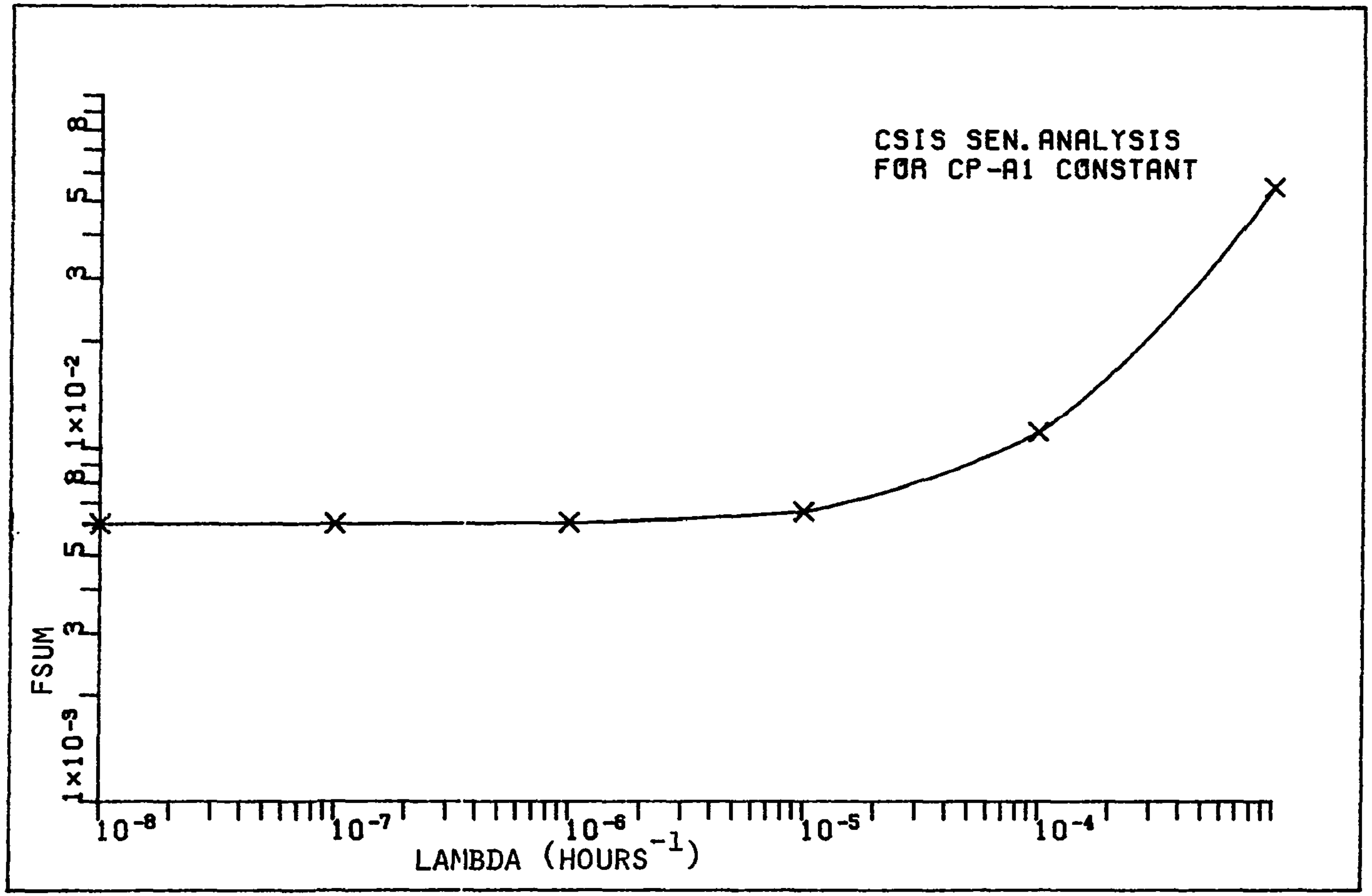

Figure 8.14. Probability of one or more failures to time 50 hours for CSIS as a function of operator error rates

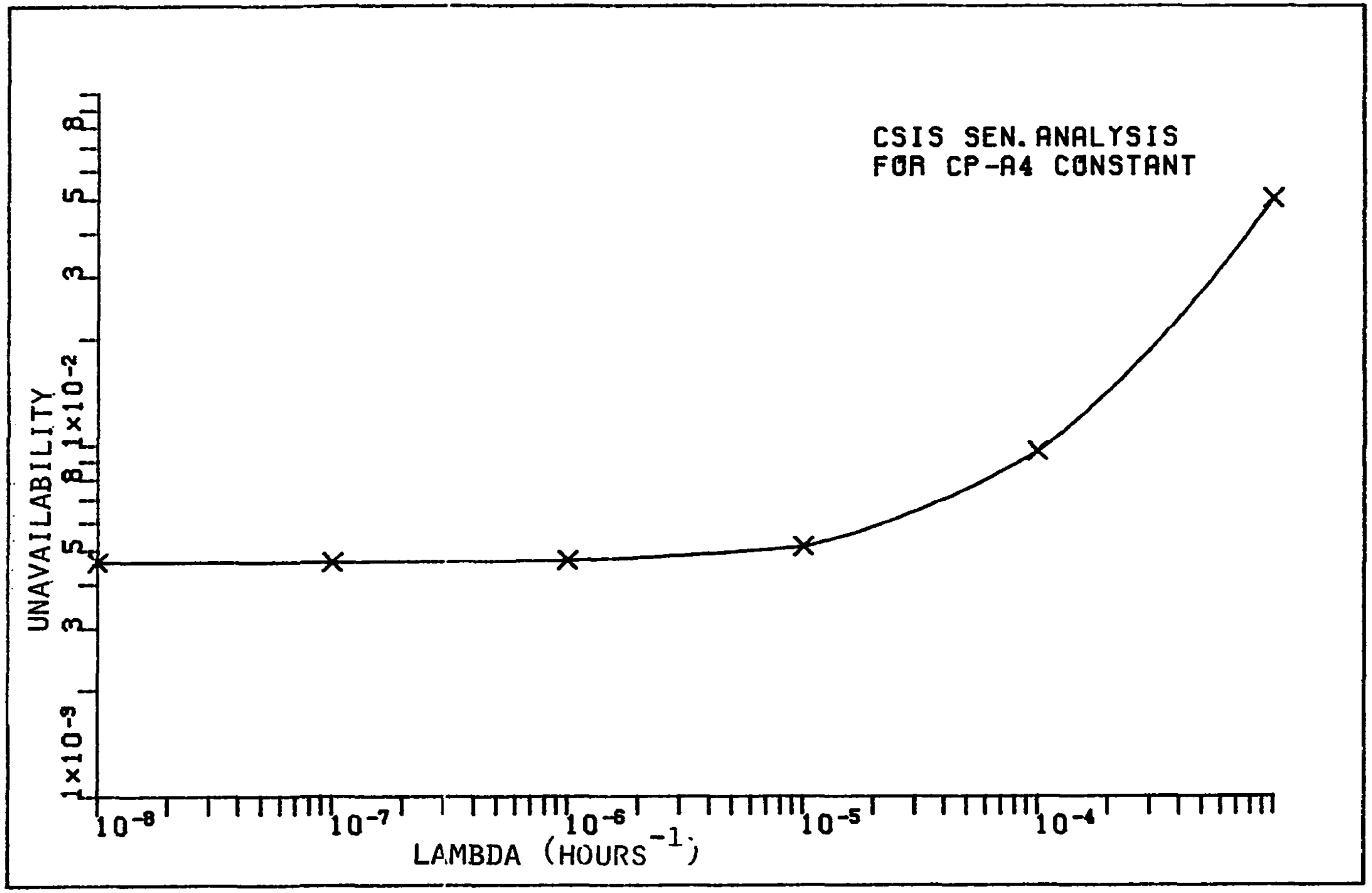

Figure 8.15. Unavailability for CSIS as a function of operator error rates at time 0 to 50 hours

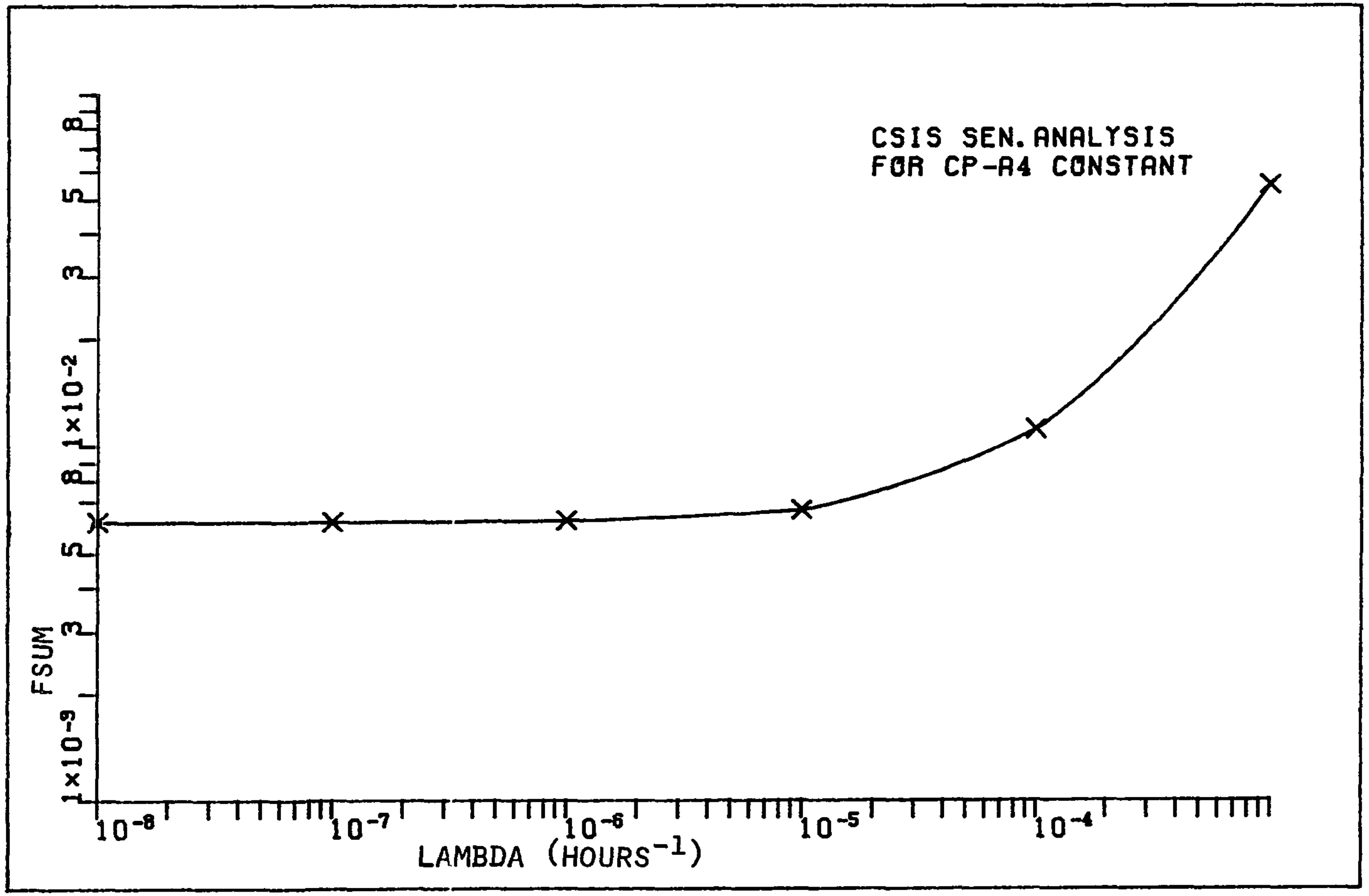

Figure 8.16. Probability of one or more failures to time 50 hours for CSIS as a function of operator error rates

8.4.5. Discussion of the results

The CSIS unavailability, Q, and the probability of one or more failure at the operation time t, FSUM, for the three cases described in section 8.3.3 are presented in Figs. 8.7 through 8.12. By reviewing these figures, one can notice that the unavailability, Q, for the three cases increases as the operation time t increases (t = 0 to 950 hours). As the operation time reaches 360 hours, the unavailability, Q, becomes flat. The reason is that time (i.e., the 360 hours) corresponds to the average repair time of the components which are presented in Tables 8.1 through 8.3. In other words, as the operation time t increases (t = 0 to 360 hours), the unavailability, Q, increases linearly with time ($Q = \lambda t$). But, as the operation time t reaches the average repair time (360 hours), no significant changes in the unavailability takes place ($Q = \lambda\tau_r$, τ_r = repair time) and the flat curve is reached. The FSUM increases as the operation time, t, increases.

The results from the KITT-1 code output for the three cases described in section 8.3.3 are summarized in Table 8.13. The results in this table show that the predicted unavailability, Q, and the FSUM of the CSIS using LERs are lower than those results obtained using WASH-1400 and NUREG/CR-1278.

Tables 8.12a and 8.12b describe the results obtained

Table 8.13. KITT-1 output results

Source of the data	Unavailability, Q, at time t = 50 hours	Probability of one or more failure at time t = 50 hours
WASH-1400	6.26×10^{-3}	7.76×10^{-3}
NUREG/CR-1278	5.24×10^{-3}	6.74×10^{-3}
LERs	4.65×10^{-3}	6.14×10^{-3}

from the sensitivity analysis. This analysis was explained in more detail in section 8.3.3. Table 8.12a describes the results obtained by keeping the operator error rate for CP-A1 constant and varying it for CP-A4, while Table 8.12b illustrates the results obtained by keeping the error rate for CP-A4 constant and varying it for CP-A1. These results are also shown in Figs. 8.13 through 8.16. As can be seen by inspection of the results shown in these figures, the unavailability, Q, and the FSUM increases as the operator error increases. This increase or change takes place slowly at operator error rate values in the ranges from 10^{-8} to 10^{-5} (error/hour) and changes very rapidly at the higher values (above 10^{-5} error/hour). The reason for this is that most of the component failure rates lie in the lower range (i.e., 10^{-8} to 10^{-5} failure/hour). At the lower part of these curves, the Q and the FSUM are dominated by the component failures and at the higher part of the curve they are dominated by human failures.

8.5. CHRS Unavailability Fault Tree

8.5.1. CHRS fault tree description

It is easy to understand the fault tree given in Fig. 8.17 by examining the simplified flow diagram of the CHRS given in Fig. 5.3.

The top event is considered to be that 3 of 4 heat exchangers (HE) do not remove sufficient heat from the spray fluid, and this will be due to one of the following events (mode events in OR gate):

(1) Three of four HE systems fail when power failure occurs.

(2) Operator error, all HE air vents left closed.

(3) Three of four HE systems fail (excluding ELEC power failures).

(4) Insufficient water in leak canal.

As shown in Fig. 8.17, one out of four events must take place in order for the top event to occur.

It was assumed that each of the above mode events takes place due to failure of its particular components. To make calculations tractable and to keep the significant events consistent with the resolution of the data available. the above fault tree is reduced before making any calculations. The reduced fault tree is shown in Fig. 8.18. The fault events code is given in Fig. 8.1. The event shown

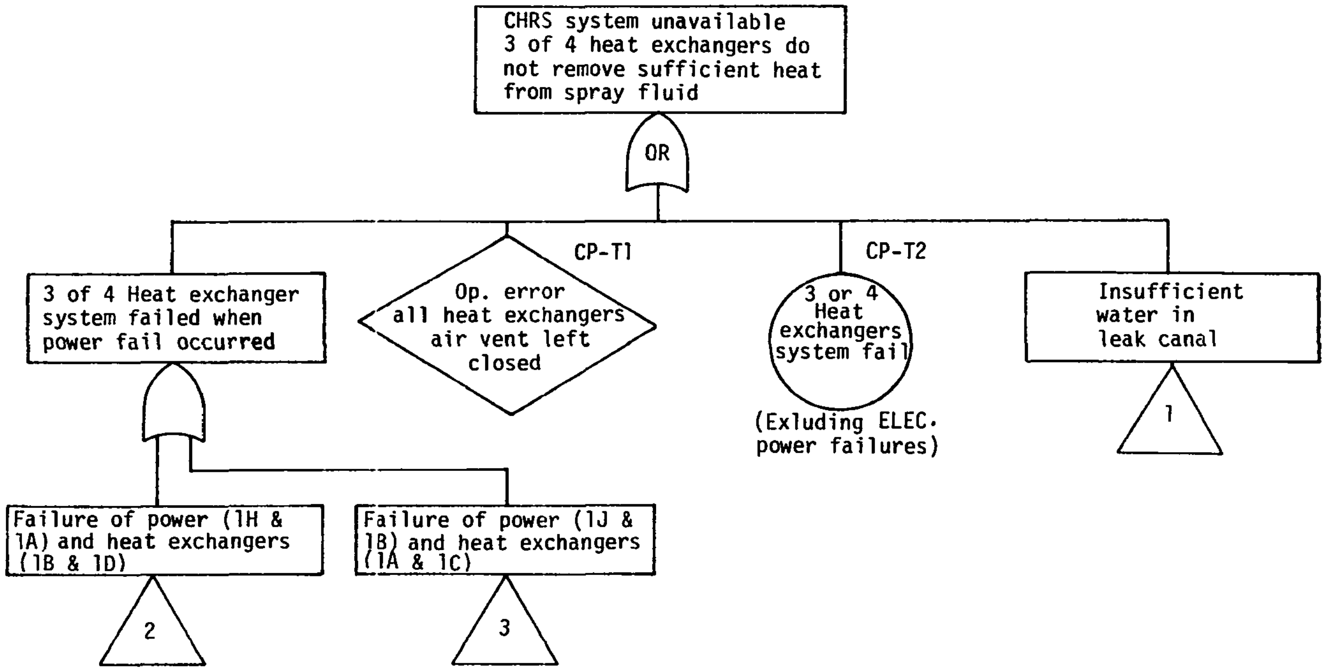

Figure 8.17. CHRS fault tree

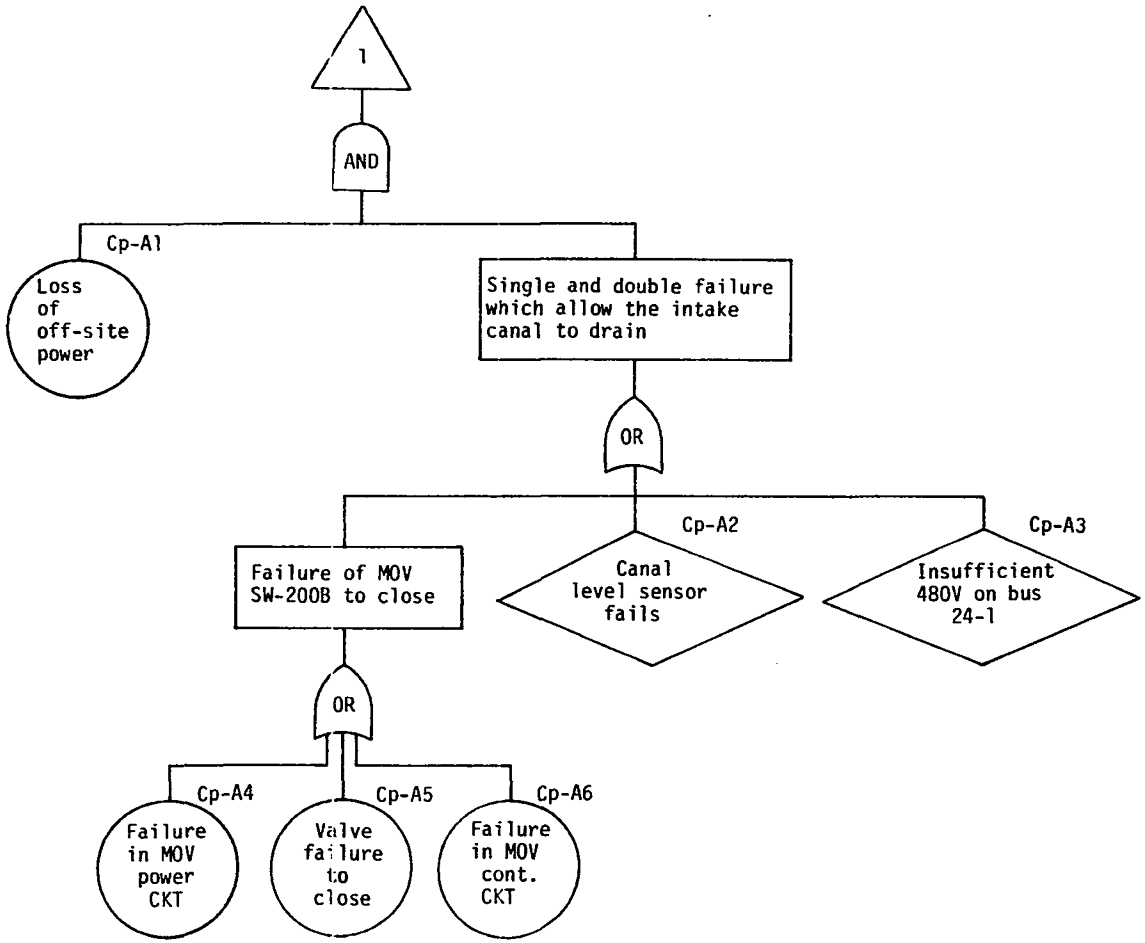

Figure 8.17. (Continued)

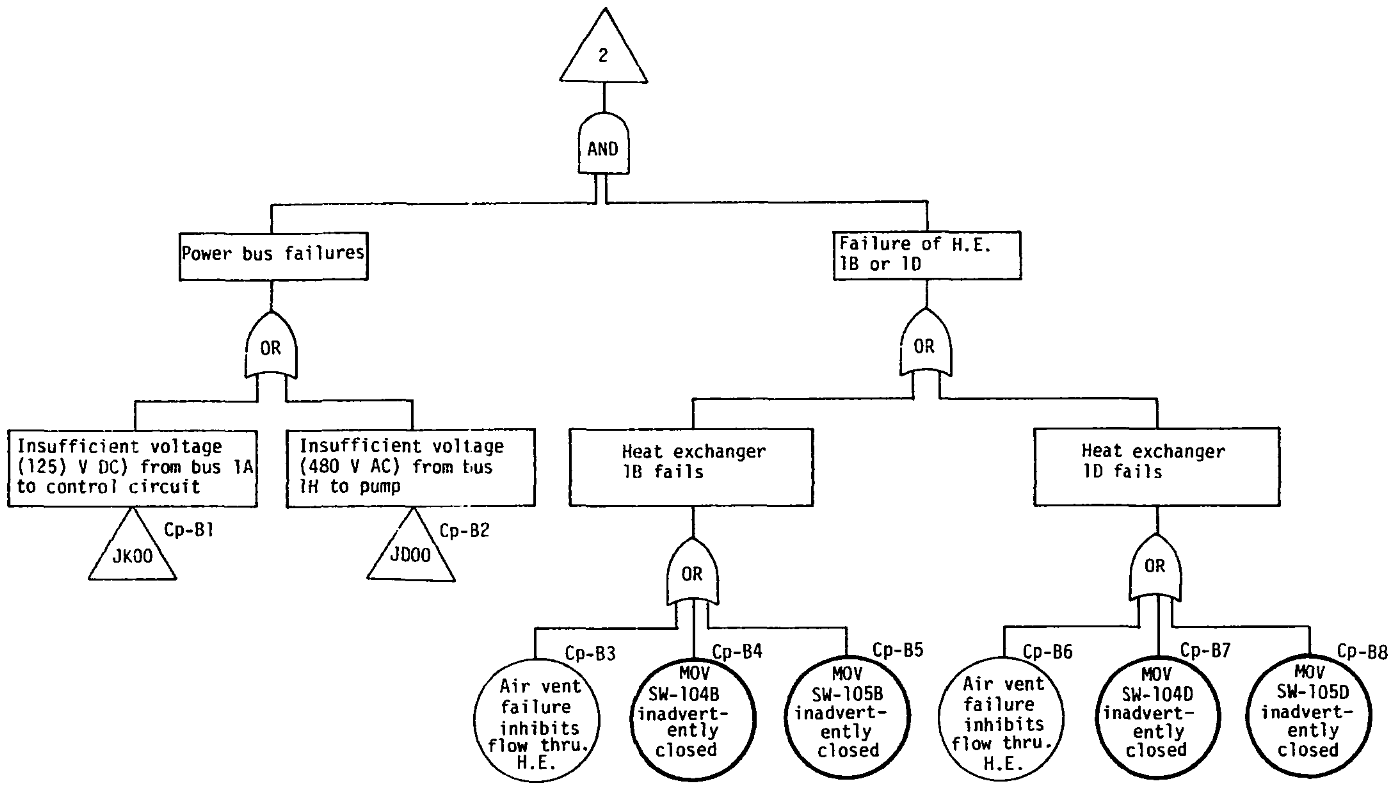

Figure 8.17. (Continued)

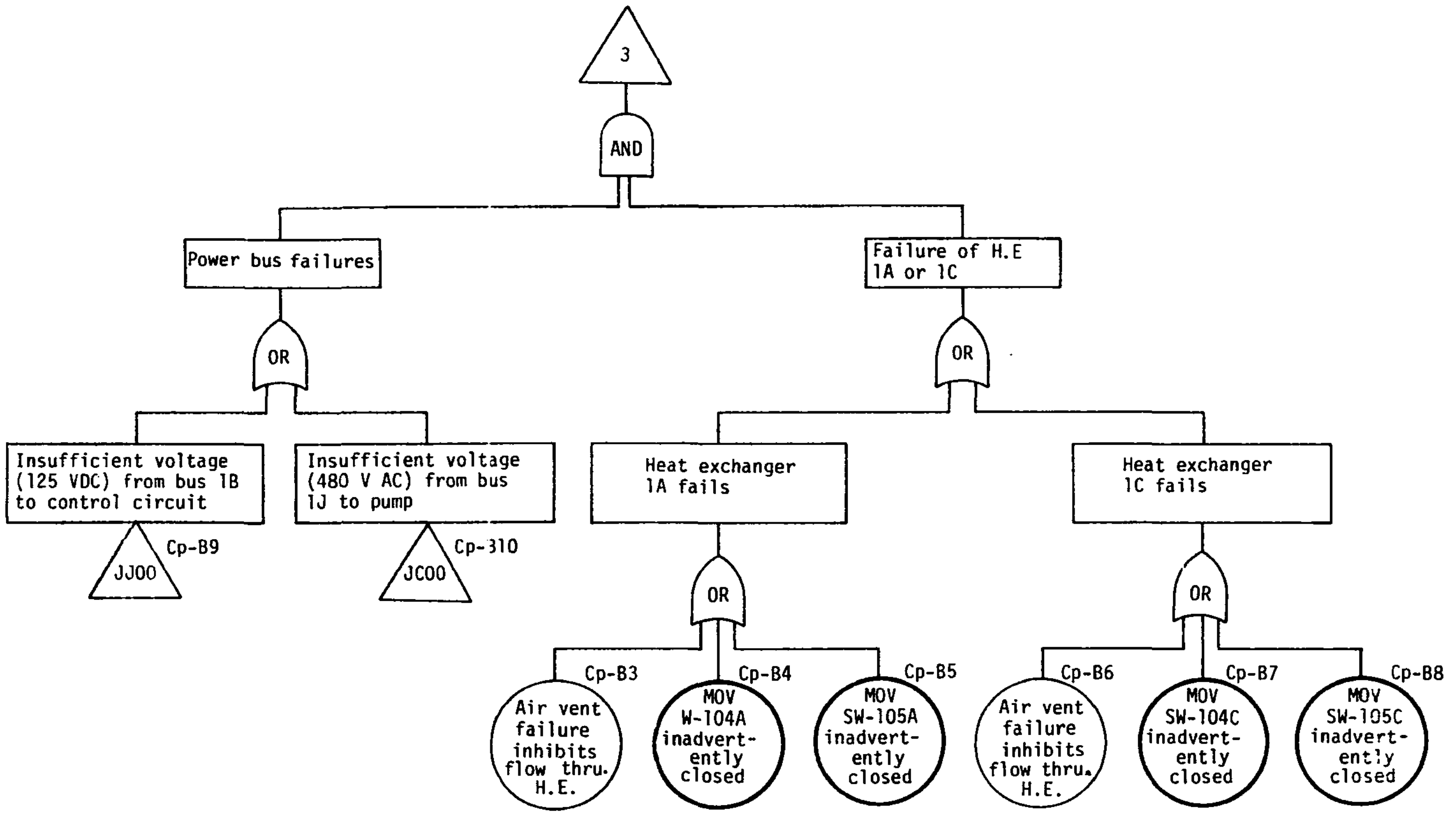

Figure 8.17. (Continued)

in Figs. 8.17 and 8.18 represent the following:

T1 = operator error, all HE air vents left closed (this event assumed as a primary event) = CAVOOOA;

T2 = 3 of 4 HE systems fail (excluding ELEC power). This event also assumed as a primary event = CHEOOOK;

A1 = loss of off-site power = COOOOON;

A2 = canal level sensor fails = CSNOOOO;

A3 = insufficient 480V on BUS 2H-1 = CBS02HP;

A4 = failure in MOV power CKT = COVOOOK;

A5 = valve failure to close = CCVOOOI;

A6 = failure in MOV CONT, CKT = CCCOOOK;

B1 = insufficient voltage (125V DC) from Bus 1A to control circuit = CBS01AP;

B2 = insufficient voltage (480V AC) from Bus 1A to pump = CBS01HP;

B3 = air vent failure inhibits flow through HE = CAVOOOQ;

B4 = MOV-SW-104B or A inadvertently closed = COV04AC;

B5 = MOV-SW-105B or A inadvertently closed = COV05AC;

B6 = air vent failure inhibits flow through HE = CAVOOOQ;

B7 = MOV-SW-104D or C inadvertently closed = COV04CC;

B8 = MOV-SW-105D or C inadvertently closed = COV05CC;

B9 = insufficient voltage (125V DC) from Bus 1B to control circuit = CBS01BP; and

B10 = insufficient voltage (480V AC) from Bus 1J to pump = CBS01JP.

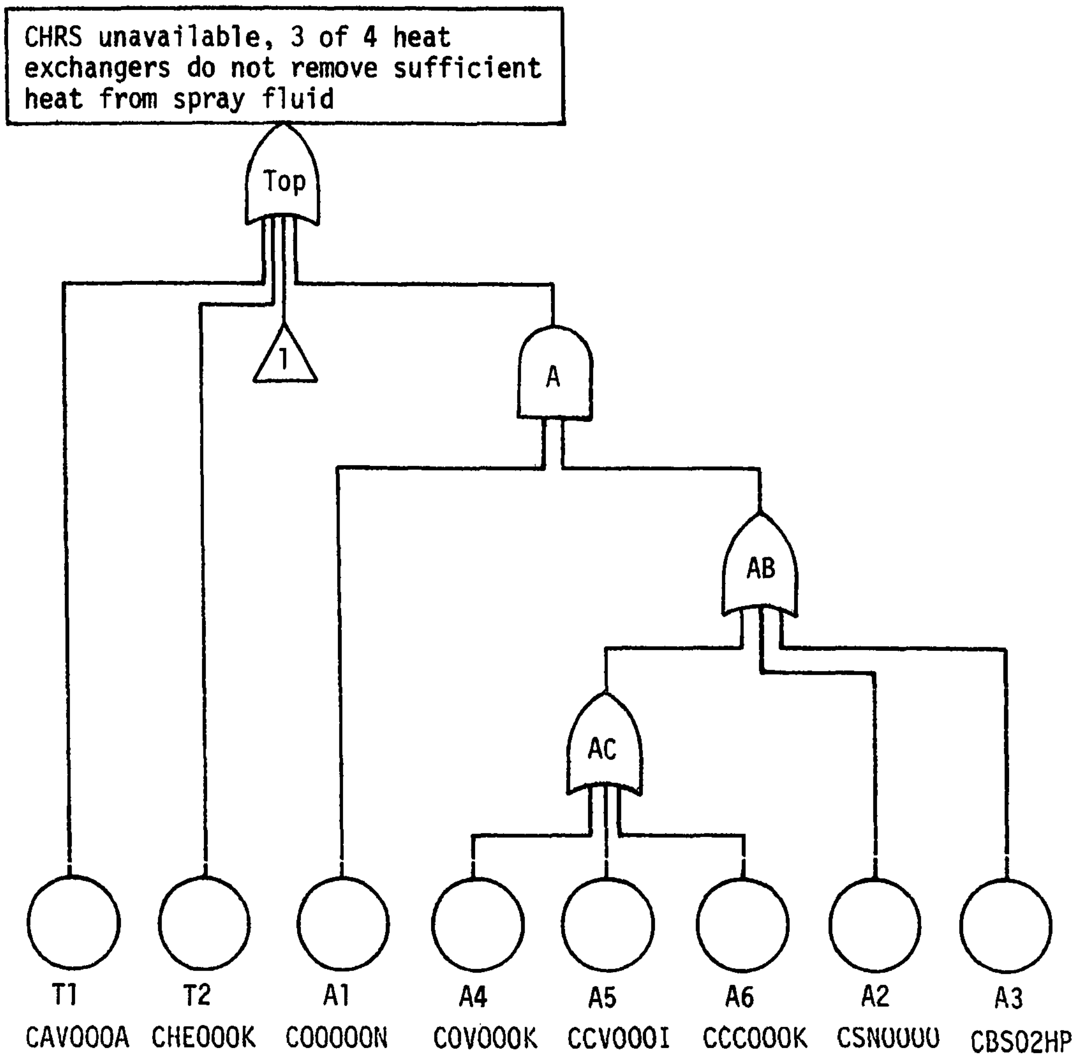

Figure 8.18. The simplified fault tree of the CSIS

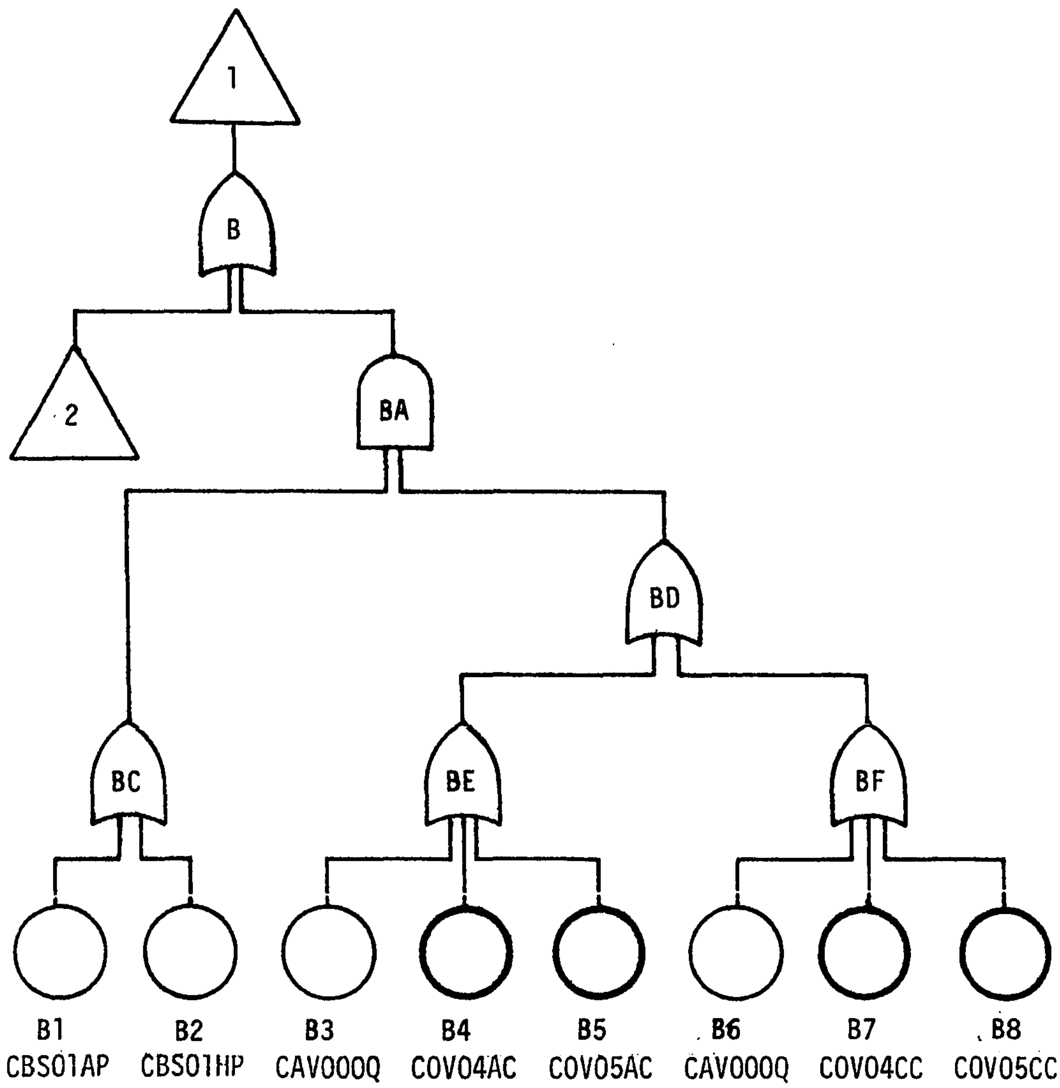

Figure 8.18. (Continued)

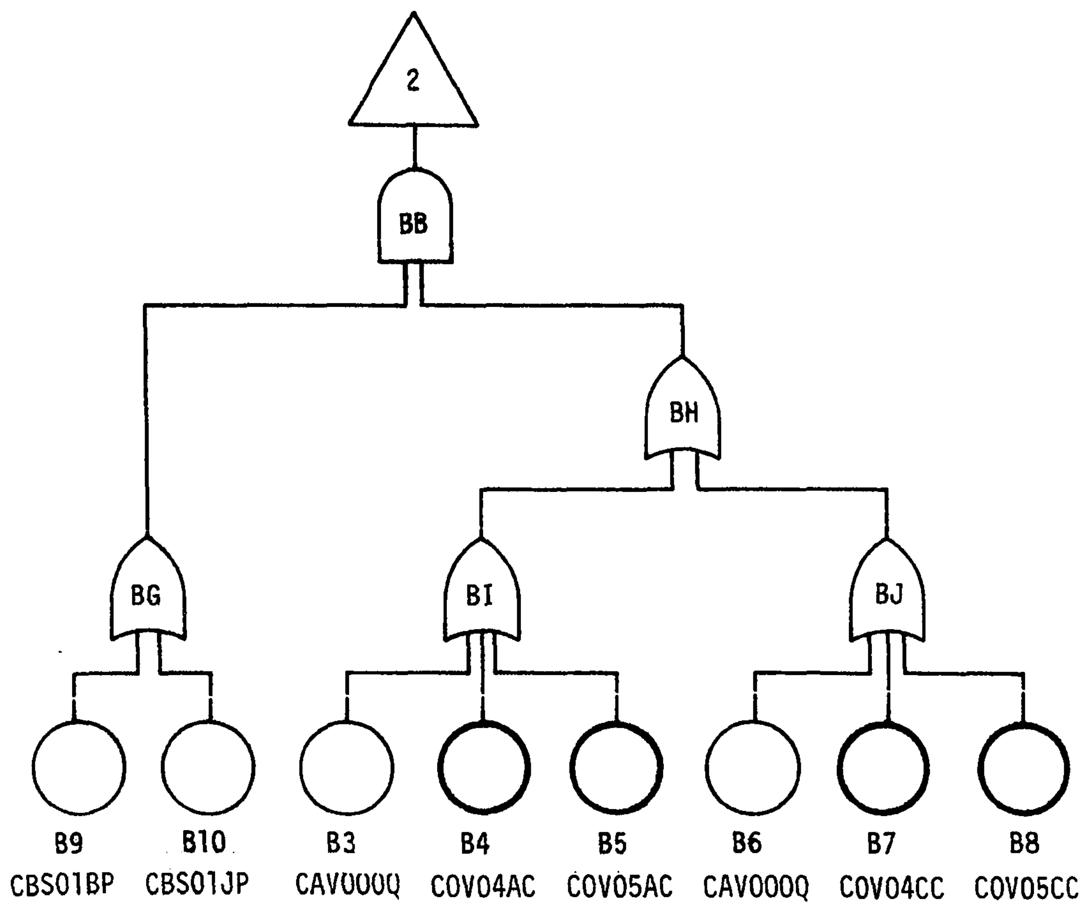

Figure 8.18. (Continued)

8.5.2. The PREP run for the CHRS unavailability fault tree

The simplified fault tree shown in Fig. 8.18 represents the input to the PREP codes. Description of the PREP and the KITT codes was previously presented in Section 8.3.2. Each unique primary event on the fault tree is assigned an arbitrary unique name. Each gate is then coded on an input card. This card gives the name of the gate and/or primary event attached to the gate. Besides the simplified fault tree, the input data necessary to use the PREP code are the component failure rate (lambdas) and repair times. WASH-1400 is used to estimate the values of the failure rate λ and the repair time τ except for human-related events. For those human-related events, the calculated human error rates presented in Sections 7.3.4 and 7.4 were used. The fault tree shown in Fig. 8.18 was analyzed using the PREP codes three different times for three different cases. In the first case, WASH-1400 was used to estimate the values of the failure rate λ and the repair time τ. These values are listed in Table 8.14. The results of this analysis are shown in Fig. 8.19.

In the second case, WASH-1400 was also used to estimate the values of the failure rate (λ) and repair time (τ) except for human-related events. The calculated human

Table 8.14. Estimated values of the failure rates/error rates and the repair time/recovery time for the components in Fig. 8.18 using data from WASH-1400

Component symbol	Failure rates/ error rates (λ) ($hours^{-1}$)	Repair time/ recovery time (hours)
CP-T1	20.0×10^{-6}	0.5
CP-T2	0.0001×10^{-6}	360
CP-A1	1.25×10^{-6}	360
CP-A2	0.0001×10^{-6}	24
CP-A3	10.3×10^{-6}	0.5
CP-A4	1.1×10^{-6}	30
CP-A5	12.0×10^{-6}	0.5
CP-A6	1.3×10^{-6}	30
CP-B1	1.2×10^{-6}	90
CP-B2	11.0×10^{-6}	38
CP-B3	1.6×10^{-6}	40
CP-B4	0.016×10^{-6}	28
CP-B5	0.26×10^{-6}	28
CP-B6	1.6×10^{-6}	40
CP-B7	0.016×10^{-6}	28
CP-B8	0.26×10^{-6}	28
CP-B9	1.2×10^{-6}	90
CP-B10	11.0×10^{-6}	38

```
*********************************************************************

*********************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
*********************************************************************


CHRS SAFTY ANALYSIS

NUMBER OF GATES,NG-------------------------   15

COMBO STARTING VALUE,MIN-------------------    1

COMBO ENDING VALUE,MAX---------------------    5

CUT SET - PATH SET SWITCH,IDEX1------------    0

PRINT - PUNCH SWITCH,IDEX2-----------------    1

MONTE CARLO STARTER,MCS--------------------    0

NO. OF RANDOM NUMBERS TO REJECT,NREJEC-----    0

NO. OF MONTE CARLO TRIALS,NTR--------------    0

MIXING PARAMETER SWITCH,IREN---------------    0

MONTE CARLO MIXING PARAMETER,TAA-----------.0
```

Figure 8.19. Output of PREP computations

```
************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
************************************************************


CHRS SAFTY ANALYSIS

          THIS IS THE SUBROUTINE GENERATED BY TREBIL
      SUBROUTINE TREE
      LOGICAL TOP,A( 500),X( 500)
      COMMON/TREES/A,X,TOP
      A(    1) = X(    1).OR.X(    2).OR.X(    3)
      A(    2) = X(    4).OR.X(    5).OR.X(    6)
      A(    3) = X(    7).OR.X(    8)
      A(    4) = X(    1).OR.X(    2).OR.X(    3)
      A(    5) = X(    4).OR.X(    5).OR.X(    6)
      A(    6) = X(    9).OR.X(   10)
      A(    7) = X(   11).OR.X(   12).OR.X(   13)
      A(    8) = A(    2).OR.A(    1)
      A(    9) = A(    5).OR.A(    4)
      A(   10) = A(    3).AND.A(    8)
      A(   11) = A(    6).AND.A(    9)
      A(   12) = A(    7)
    *          .OR.X(   14).OR.X(   15)
      A(   13) = A(   11).OR.A(   10)
      A(   14) = A(   12)
    *          .AND.X(   16)
      A(   15) = A(   14).OR.A(   13)
    *          .OR.X(   17).OR.X(   18)
      TOP = A(   15)
      RETURN
      END
```

Figure 8.19. (Continued)

```
*******************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM                                           *
*******************************************************************************
```

CHRS SAFTY ANALYSIS

COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	CP-B6	1.60000D-06	4.00000D 01
2	CP-B7	1.60000D-08	2.80000D 01
3	CP-B8	2.60000D-07	2.80000D 01
4	CP-B3	1.60000D-06	4.00000D 01
5	CP-B4	1.60000D-08	2.80000D 01
6	CP-B5	2.60000D-08	2.80000D 01
7	CP-B9	1.20000D-06	9.00000D 01
8	CP-B10	1.10000D-05	3.80000D 01
9	CP-B1	1.20000D-06	9.00000D 01
10	CP-B2	1.10000D-05	3.80000D 01
11	CP-A4	1.10000D-06	3.00000D 01
12	CP-A5	1.20000D-05	5.00000D-01
13	CP-A6	1.30000D-06	3.00000D 01
14	CP-A2	1.00000D-10	2.40000D 01
15	CP-A3	1.03000D-05	5.00000D-01
16	CP-A1	1.25000D-06	3.60000D 02
17	CP-T1	2.00000D-05	5.00000D-01
18	CP-T2	1.00000D-10	3.60000D 02

Figure 8.19. (Continued)

```
****************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
****************************************************************


CHRS SAFTY ANALYSIS

NAME      TYPE      INPUTS----
TOP       OR    2 2 GT-A      GT-B      CP-T1     CP-T2
GT-A      AND   1 1 GT-AB     CP-A1
GT-B      OR    2 0 GT-BA     GT-BB
GT-AB     OR    1 2 GT-AC     CP-A2     CP-A3
GT-AC     OR    0 3 CP-A4     CP-A5     CP-A6
GT-BA     AND   2 0 GT-BC     GT-BD
GT-BB     AND   2 0 GT-BG     GT-BH
GT-BC     OR    0 2 CP-B1     CP-B2
GT-BD     OR    2 0 GT-BE     GT-BF
GT-BE     OR    0 3 CP-B3     CP-B4     CP-B5
GT-BF     OR    0 3 CP-B6     CP-B7     CP-B8
GT-BG     OR    0 2 CP-B9     CP-B10
GT-BH     OR    2 0 GT-BI     GT-BJ
GT-BI     OR    0 3 CP-B3     CP-B4     CP-B5
GT-BJ     OR    0 3 CP-B6     CP-B7     CP-B8
END             0 0
```

Figure 8.19. (Continued)

```
*****************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
*****************************************************************


CHRS SAFTY ANALYSIS

TREE INDEX   GATE NAME    INPUTS--
         1    GT-BJ        OR        CP-B6      CP-B7      CP-B8
         2    GT-BI        OR        CP-B3      CP-B4      CP-B5
         3    GT-BG        OR        CP-B9      CP-B10
         4    GT-BF        OR        CP-B6      CP-B7      CP-B8
         5    GT-BE        OR        CP-B3      CP-B4      CP-B5
         6    GT-BC        OR        CP-B1      CP-B2
         7    GT-AC        OR        CP-A4      CP-A5      CP-A6
         8    GT-BH        OR        GT-BI      GT-BJ
         9    GT-BD        OR        GT-BE      GT-BF
        10    GT-BB        AND       GT-BG      GT-BH
        11    GT-BA        AND       GT-BC      GT-BD
        12    GT-AB        OR        GT-AC      CP-A2      CP-A3
        13    GT-B         OR        GT-BA      GT-BB
        14    GT-A         AND       GT-AB      CP-A1
        15    TOP          OR        GT-A       GT-B       CP-T1      CP-T2
```

Figure 8.19. (Continued)

****
TREBIL FAULT TREE BUILDING PROGRAM*
****
CHRS SAFTY ANALYSIS

TREE INDEX	COMPONENT NAME	NUMBER OF GATES INPUT	GATES INPUT	
1	CP-B6	2	GT-BJ	GT-BF
2	CP-B7	2	GT-BJ	GT-BF
3	CP-B8	2	GT-BJ	GT-BF
4	CP-B3	2	GT-BI	GT-BE
5	CP-B4	2	GT-BI	GT-BE
6	CP-B5	2	GT-BI	GT-BE
7	CP-B9	1	GT-BG	
8	CP-B10	1	GT-BG	
9	CP-B1	1	GT-BC	
10	CP-B2	1	GT-BC	
11	CP-A4	1	GT-AC	
12	CP-A5	1	GT-AC	
13	CP-A6	1	GT-AC	
14	CP-A2	1	GT-AB	
15	CP-A3	1	GT-AB	
16	CP-A1	1	GT-A	
17	CP-T1	1	TOP	
18	CP-T2	1	TOP	

Figure 8.19. (Continued)

error rates (using LERs) presented in Section 7.3.3 were used. These values are listed in Table 8.15. The fault tree shown in Fig. 8.18 was analyzed again using the PREP codes, and the results are shown in Fig. 8.20.

Table 8.15. Estimated values of the failure rates/error rates and the repair time/recovery time for the components in Fig. 8.18 using data extracted from LERs

Component symbol	Failure rates/ error rates (λ) (hours^{-1})	Repair time/ recovery time (hours)
CP-T1	20.0×10^{-6}	0.5
CP-T2	0.0001×10^{-6}	360.0
CP-A1	1.25×10^{-6}	360.0
CP-A2	0.0001×10^{-6}	24.0
CP-A3	10.3×10^{-6}	0.5
CP-A4	1.1×10^{-6}	30.0
CP-A5	12.0×10^{-6}	0.5
CP-A6	1.3×10^{-6}	30.0
CP-B1	1.2×10^{-6}	90.0
CP-B2	11.0×10^{-6}	38.0
CP-B3	1.6×10^{-6}	40.0
CP-B4	1.478×10^{-6}	28.0
CP-B5	1.478×10^{-6}	28.0
CP-B6	1.6×10^{-6}	40.0
CP-B7	1.478×10^{-6}	28.0
CP-B8	1.478×10^{-6}	28.0
CP-B9	1.2×10^{-6}	90.0
CP-B10	11.0×10^{-6}	38.0

```
*************************************************************

*************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
*************************************************************


CHRS SAFTY ANALYSIS

NUMBER OF GATES,NG-------------------------        15

COMBO STARTING VALUE,MIN-------------------         1

COMBO ENDING VALUE,MAX---------------------         5

CUT SET - PATH SET SWITCH,IDEX1------------         0

PRINT - PUNCH SWITCH,IDEX2-----------------         1

MONTE CARLO STARTER,MCS--------------------         0

NO. OF RANDOM NUMBERS TO REJECT,NREJEC-----         0

NO. OF MONTE CARLO TRIALS,NTR--------------         0

MIXING PARAMETER SWITCH,IREN---------------         0

MONTE CARLO MIXING PARAMETER,TAA------------.0
```

Figure 8.20. Output of PREP computation

```
****************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
****************************************************************


CHRS SAFTY ANALYSIS

          THIS IS THE SUBROUTINE GENERATED BY TREBIL
      SUBROUTINE TREE
      LOGICAL TOP,A( 500),X( 500)
      COMMON/TREES/A,X,TOP
      A(    1) = X(    1).OR.X(    2).OR.X(    3)
      A(    2) = X(    4).OR.X(    5).OR.X(    6)
      A(    3) = X(    7).OR.X(    8)
      A(    4) = X(    1).OR.X(    2).OR.X(    3)
      A(    5) = X(    4).OR.X(    5).OR.X(    6)
      A(    6) = X(    9).OR.X(   10)
      A(    7) = X(   11).OR.X(   12).OR.X(   13)
      A(    8) = A(    2).OR.A(    1)
      A(    9) = A(    5).OR.A(    4)
      A(   10) = A(    3).AND.A(    8)
      A(   11) = A(    6).AND.A(    9)
      A(   12) = A(    7)
     *          .OR.X(   14).OR.X(   15)
      A(   13) = A(   11).OR.A(   10)
      A(   14) = A(   12)
     *          .AND.X(   16)
      A(   15) = A(   14).OR.A(   13)
     *          .OR.X(   17).OR.X(   18)
      TOP = A(   15)
      RETURN
      END
```

Figure 8.20. (Continued)

```
**********************************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM                                                        *
**********************************************************************************************
```

CHRS SAFTY ANALYSIS

COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	CP-B6	1.60000D-06	4.00000D 01
2	CP-B7	1.47800D-07	2.80000D 01
3	CP-B8	1.47800D-07	2.80000D 01
4	CP-B3	1.60000D-06	4.00000D 01
5	CP-B4	1.47800D-07	2.80000D 01
6	CP-B5	1.47800D-07	2.80000D 01
7	CP-B9	1.20000D-06	9.00000D 01
8	CP-B10	1.10000D-05	3.80000D 01
9	CP-B1	1.20000D-06	9.00000D 01
10	CP-B2	1.10000D-05	3.80000D 01
11	CP-A4	1.10000D-06	3.00000D 01
12	CP-A5	1.20000D-05	5.00000D-01
13	CP-A6	1.30000D-06	3.00000D 01
14	CP-A2	1.00000D-10	2.49000D 01
15	CP-A3	1.03000D-05	5.00000D-01
16	CP-A1	1.25000D-06	3.60000D 02
17	CP-T1	2.00000D-05	5.00000D-01
18	CP-T2	1.00000D-10	3.60000D 02

Figure 8.20. (Continued)

```
*****************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
*****************************************************


CHRS SAFTY ANALYSIS

NAME      TYPE     INPUTS----
TOP       OR    2 2 GT-A      GT-B      CP-T1     CP-T2
GT-A      AND   1 1 GT-AB     CP-A1
GT-B      OR    2 0 GT-BA     GT-BB
GT-AB     OR    1 2 GT-AC     CP-A2     CP-A3
GT-AC     OR    0 3 CP-A4     CP-A5     CP-A6
GT-BA     AND   2 0 GT-BC     GT-BD
GT-BB     AND   2 0 GT-BG     GT-BH
GT-BC     OR    0 2 CP-B1     CP-B2
GT-BD     OR    2 0 GT-BE     GT-BF
GT-BE     OR    0 3 CP-B3     CP-B4     CP-B5
GT-BF     OR    0 3 CP-B6     CP-B7     CP-B8
GT-BG     OR    0 2 CP-B9     CP-B10
GT-BH     OR    2 0 GT-BI     GT-BJ
GT-BI     OR    0 3 CP-B3     CP-B4     CP-B5
GT-BJ     OR    0 3 CP-B6     CP-B7     CP-B8
END             0 0
```

Figure 8.20. (Continued)

```
*****************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
*****************************************************************************


CHRS SAFTY ANALYSIS

TREE INDEX  GATE NAME   INPUTS--
         1   GT-BJ      OR         CP-B6      CP-B7      CP-B8
         2   GT-BI      OR         CP-B3      CP-B4      CP-B5
         3   GT-BG      OR         CP-B9      CP-B10
         4   GT-BF      OR         CP-B6      CP-B7      CP-B8
         5   GT-BE      OR         CP-B3      CP-B4      CP-B5
         6   GT-BC      OR         CP-B1      CP-B2
         7   GT-AC      OR         CP-A4      CP-A5      CP-A6
         8   GT-BH      OR         GT-BI      GT-BJ
         9   GT-BD      OR         GT-BE      GT-BF
        10   GT-BB      AND        GT-BG      GT-BH
        11   GT-BA      AND        GT-BC      GT-BD
        12   GT-AB      OR         GT-AC      CP-A2      CP-A3
        13   GT-B       OR         GT-BA      GT-BB
        14   GT-A       AND        GT-AB      CP-A1
        15   TOP        OR         GT-A       GT-B       CP-T1      CP-T2
```

Figure 8.20. (Continued)

```
*************************************************************************
TREBIL FAULT TREE BUILDING PROGRAM*
*************************************************************************
CHRS SAFTY ANALYSIS
```

TREE INDEX	COMPONENT NAME	NUMBER OF GATES INPUT	GATES INPUT	
1	CP-B6	2	GT-BJ	GT-BF
2	CP-B7	2	GT-BJ	GT-BF
3	CP-B8	2	GT-BJ	GT-BF
4	CP-B3	2	GT-BI	GT-BE
5	CP-B4	2	GT-BI	GT-BE
6	CP-B5	2	GT-BI	GT-BE
7	CP-B9	1	GT-BG	
8	CP-B10	1	GT-BG	
9	CP-B1	1	GT-BC	
10	CP-B2	1	GT-BC	
11	CP-A4	1	GT-AC	
12	CP-A5	1	GT-AC	
13	CP-A6	1	GT-AC	
14	CP-A2	1	GT-AB	
15	CP-A3	1	GT-AB	
16	CP-A1	1	GT-A	
17	CP-T1	1	TOP	
18	CP-T2	1	TOP	

Figure 8.20. (Continued)

In the third case, WASH-1400 again was used to estimate the values of the failure rate λ and the repair time τ. For human events (CP-B4, CP-B5, CP-B7 and CP-B8), the calculated human error rates using NUREG/CR-1278 (11) presented in Section 7.4 were used. These values are listed in Table 8.16. The fault tree shown in Fig. 8.18 was analyzed again using the PREP codes, and the results are shown in Fig. 8.21.

Table 8.16. Estimated values of the failure rates/error rates and the repair time/recovery time for the components in Fig. 8.18 using data from NUREG/CR-1278

Component symbol	Failure rates/ error rates (λ) (hours^{-1})	Repair time/ recovery time (hours)
CP-T1	20.0×10^{-6}	0.5
CP-T2	0.0001×10^{-6}	360.0
CP-A1	1.25×10^{-6}	360.0
CP-A2	0.0001×10^{-6}	24.0
CP-A3	10.3×10^{-6}	0.5
CP-A4	1.1×10^{-6}	30.0
CP-A5	12.0×10^{-6}	0.5
CP-A6	1.3×10^{-6}	30.0
CP-B1	1.2×10^{-6}	90.0
CP-B2	11.0×10^{-6}	38.0
CP-B3	1.686×10^{-6}	40.0
CP-B4	1.786×10^{-6}	28.0
CP-B5	2.976×10^{-6}	28.0
CP-B6	1.6×10^{-6}	40.0
CP-B7	1.786×10^{-6}	28.0
CP-B8	2.976×10^{-6}	28.0
CP-B9	1.2×10^{-6}	90.0
CP-10	11.0×10^{-6}	38.0

```
*************************************************************

*************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
*************************************************************


CHRS SAFTY ANALYSIS

NUMBER OF GATES,NG------------------------   15

COMBO STARTING VALUE,MIN-----------------    1

COMBO ENDING VALUE,MAX-------------------    5

CUT SET - PATH SET SWITCH,IDEX1----------    0

PRINT - PUNCH SWITCH,IDEX2---------------    1

MONTE CARLO STARTER,MCS------------------    0

NO. OF RANDOM NUMBERS TO REJECT,NREJEC---    0

NO. OF MONTE CARLO TRIALS,NTR------------    0

MIXING PARAMETER SWITCH,IREN-------------    0

MONTE CARLO MIXING PARAMETER,TAA----------.0
```

Figure 8.21. Output of PREP computations

```
***********************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
***********************************************************


CHRS SAFTY ANALYSIS

          THIS IS THE SUBROUTINE GENERATED BY TREBIL
      SUBROUTINE TREE
      LOGICAL TOP,A( 500),X( 500)
      COMMON/TREES/A,X,TOP
      A(    1) = X(    1).OR.X(    2).OR.X(    3)
      A(    2) = X(    4).OR.X(    5).OR.X(    6)
      A(    3) = X(    7).OR.X(    8)
      A(    4) = X(    1).OR.X(    2).OR.X(    3)
      A(    5) = X(    4).OR.X(    5).OR.X(    6)
      A(    6) = X(    9).OR.X(   10)
      A(    7) = X(   11).OR.X(   12).OR.X(   13)
      A(    8) = A(    2).OR.A(    1)
      A(    9) = A(    5).OR.A(    4)
      A(   10) = A(    3).AND.A(    8)
      A(   11) = A(    6).AND.A(    9)
      A(   12) = A(    7)
     *         .OR.X(   14).OR.X(   15)
      A(   13) = A(   11).OR.A(   10)
      A(   14) = A(   12)
     *         .AND.X(   16)
      A(   15) = A(   14).OR.A(   13)
     *         .OR.X(   17).OR.X(   18)
      TOP = A(   15)
      RETURN
      END
```

Figure 8.21. (Continued)

```
*****************************************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM                                                    *
*****************************************************************************************
```

CHRS SAFTY ANALYSIS

COMPONENT INDICES, NAMES, AND FAILURE RATES (PER HOUR) -

TREE INDEX	COMPONENT NAME	LAMBDA(FAILURE INTENSITY/HR.)	TAU
1	CP-B6	1.60000D-06	4.00000D 01
2	CP-B7	1.78600D-06	2.80000D 01
3	CP-B8	2.98000D-06	2.80000D 01
4	CP-B3	1.60000D-06	4.00000D 01
5	CP-B4	1.79000D-06	2.80000D 01
6	CP-B5	2.97600D-06	2.80000D 01
7	CP-B9	1.20000D-06	9.00000D 01
8	CP-B10	1.10000D-05	3.80000D 01
9	CP-B1	1.20000D-06	9.00000D 01
10	CP-B2	1.10000D-05	3.80000D 01
11	CP-A4	1.10000D-06	3.00000D 01
12	CP-A5	1.20000D-05	5.00000D-01
13	CP-A6	1.30000D-06	3.00000D 01
14	CP-A2	1.00000D-10	2.40000D 01
15	CP-A3	1.03000D-05	5.00000D-01
16	CP-A1	1.25000D-06	3.60000D 02
17	CP-T1	2.00000D-05	5.00000D-01
18	CP-T2	1.00000D-10	3.60000D 02

Figure 8.21. (Continued)

```
***********************************************************:
*TREBIL FAULT TREE BUILDING PROGRAM
***********************************************************:


CHRS SAFTY ANALYSIS

NAME      TYPE     INPUTS----
TOP       OR    2 2 GT-A      GT-B      CP-T1     CP-T2
GT-A      AND   1 1 GT-AB     CP-A1
GT-B      OR    2 0 GT-BA     GT-BB
GT-AB     OR    1 2 GT-AC     CP-A2     CP-A3
GT-AC     OR    0 3 CP-A4     CP-A5     CP-A6
GT-BA     AND   2 0 GT-BC     GT-BD
GT-BB     AND   2 0 GT-BG     GT-BH
GT-BC     OR    0 2 CP-B1     CP-B2
GT-BD     OR    2 0 GT-BE     GT-BF
GT-BE     OR    0 3 CP-B3     CP-B4     CP-B5
GT-BF     OR    0 3 CP-B6     CP-B7     CP-B8
GT-BG     OR    0 2 CP-B9     CP-B10
GT-BH     OR    2 0 GT-BI     GT-BJ
GT-BI     OR    0 3 CP-B3     CP-B4     CP-B5
GT-BJ     OR    0 3 CP-B6     CP-B7     CP-B8
END             0 0
```

Figure 8.21. (Continued)

```
************************************************************
*TREBIL FAULT TREE BUILDING PROGRAM
************************************************************


CHRS SAFTY ANALYSIS

TREE INDEX  GATE NAME   INPUTS--
         1   GT-BJ     OR        CP-B6     CP-B7     CP-B8
         2   GT-BI     OR        CP-B3     CP-B4     CP-B5
         3   GT-BG     OR        CP-B9     CP-B10
         4   GT-BF     OR        CP-B6     CP-B7     CP-B8
         5   GT-BE     OR        CP-B3     CP-B4     CP-B5
         6   GT-BC     OR        CP-B1     CP-B2
         7   GT-AC     OR        CP-A4     CP-A5     CP-A6
         8   GT-BH     OR        GT-BI     GT-BJ
         9   GT-BD     OR        GT-BE     GT-BF
        10   GT-BB     AND       GT-BG     GT-BH
        11   GT-BA     AND       GT-BC     GT-BD
        12   GT-AB     OR        GT-AC     CP-A2     CP-A3
        13   GT-B      OR        GT-BA     GT-BB
        14   GT-A      AND       GT-AB     CP-A1
        15   TOP       OR        GT-A      GT-B      CP-T1     CP-T2
```

Figure 8.21. (Continued)

****

TREBIL FAULT TREE BUILDING PROGRAM*

****

CHRS SAFTY ANALYSIS

TREE INDEX	COMPONENT NAME	NUMBER OF GATES INPUT	GATES INPUT	
1	CP--B6	2	GT-BJ	GT-BF
2	CP--B7	2	GT-BJ	GT-BF
3	CP--B8	2	GT-BJ	GT-BF
4	CP--B3	2	GT-BI	GT-BE
5	CP--B4	2	GT-BI	GT-BE
6	CP--B5	2	GT-BI	GT-BE
7	CP--B9	1	GT-BG	
8	CP--B10	1	GT-BG	
9	CP--B1	1	GT-BC	
10	CP--B2	1	GT-BC	
11	CP--A4	1	GT-AC	
12	CP--A5	1	GT-AC	
13	CP--A6	1	GT-AC	
14	CP--A2	1	GT-AB	
15	CP--A3	1	GT-AB	
16	CP--A1	1	GT-A	
17	CP--T1	1	TOP	
18	CP--T2	1	TOP	

Figure 8.21. (Continued)

8.5.3. KITT-1 results for CHRS unavailability fault tree

8.5.3.1. Case 1: WASH-1400 Having obtained the minimal cut sets from the PREPS, the KITT-1 codes were then run to obtain the probability characteristics associated with "three of four HE in CHRS removing insufficient heat from spray fluid using FTA." The results from the KITT-1 code include system differential and integral characteristics, the inhibit characteristics of every component, and the minimal cut sets characteristics. The results from KITT-1 are shown in Appendix F. Some of the component inhibit characteristics obtained from the KITT-1 codes run are summarized in Table 8.17.

Table 8.17. Some component characteristics resulting from KITT-1 run for CHRS using WASH-1400 data (case 1) at operation time of 60 hours

Component or event	Unavailability (Q) (per hour)	Probability of one or more failure to time t (FSUM)
1	6.4×10^{-5}	9.6×10^{-5}
3	7.28×10^{-6}	1.55×10^{-5}
5	4.48×10^{-7}	9.6×10^{-5}
7	7.2×10^{-5}	7.2×10^{-5}
8	4.18×10^{-4}	6.59×10^{-4}
11	3.3×10^{-5}	9.89×10^{-5}
12	5.9×10^{-6}	7.19×10^{-4}
13	3.89×10^{-5}	7.8×10^{-5}
15	5.15×10^{-6}	6.18×10^{-4}
16	7.49×10^{-5}	7.5×10^{-5}
17	9.9×10^{-6}	1.19×10^{-3}

The program output symbols are defined as follows:

T = t, time (in hours);

Q = $\underset{\sim}{q}(t)$, the component failed probability;

W = w(t), the component failure rate (per hour);

L = the (input) component failure intensity (per hour);

WSUM = the expected number of failures to time t; and

FSUM = the probability of one or more failures to time t.

The characteristics of some of the minimal cut sets obtained from the KITT-1 codes run are summarized in Table 8.18, where the program output symbols are defined as

Table 8.18. Minimal cut set characteristics resulting from KITT-1 code run for CHRS using WASH-1400 data (case 1) at operation time of 60 hours

Minimal cut set	Unavailability (Q) (per hour)	Probability of one or more failure to time t (FSUM)
1	9.99×10^{-6}	5.99×10^{-4}
5	2.62×10^{-10}	2.71×10^{-10}
9	1.48×10^{-10}	1.53×10^{-10}
11	2.4×10^{-9}	2.48×10^{-9}
16	1.61×10^{-11}	1.67×10^{-11}
23	2.4×10^{-9}	2.48×10^{-9}
25	1.48×10^{-10}	1.53×10^{-10}
28	2.25×10^{-10}	6.86×10^{-9}
30	8.9×10^{-14}	1.01×10^{-13}
31	1.93×10^{-10}	5.89×10^{-9}

follows:

T = t, time (in hours);

Q = $\underset{\sim}{q}(t)$, the minimal cut set failure probability;

W = w(t), the minimal cut set failure rate (per hour); and

L = A(t), the minimal cut set failure intensity (per hour).

Some of the system differential and integral characteristics resulting from the KITT-1 codes run are summarized below in Table 8.19 and plotted in Figs. 8.22 and 8.23 where the program output symbols are defined in Section 8.4.1.

Table 8.19. Some system characteristics resulting from KITT-1 code run for CHRS using WASH-1400 data (case 1)

T(hours)	Unavailability (Q) (per demand)	Probability of one or failure to time t (FSUM)
0.0	0.0	--
30.0	1.008×10^{-5}	5.99×10^{-4}
60.0	1.014×10^{-5}	1.19×10^{-3}
90.0	1.016×10^{-5}	1.79×10^{-3}
150.0	1.017×10^{-5}	2.99×10^{-3}
210.0	1.018×10^{-5}	4.19×10^{-3}
270.0	1.019×10^{-5}	5.38×10^{-3}
300.0	1.020×10^{-5}	5.98×10^{-3}
330.0	1.021×10^{-5}	6.58×10^{-3}
360.0	1.021×10^{-5}	7.58×10^{-3}
420.0	1.021×10^{-5}	8.37×10^{-3}
480.0	1.021×10^{-5}	9.56×10^{-3}
540.0	1.021×10^{-5}	1.08×10^{-2}
570.0	1.021×10^{-5}	1.14×10^{-2}

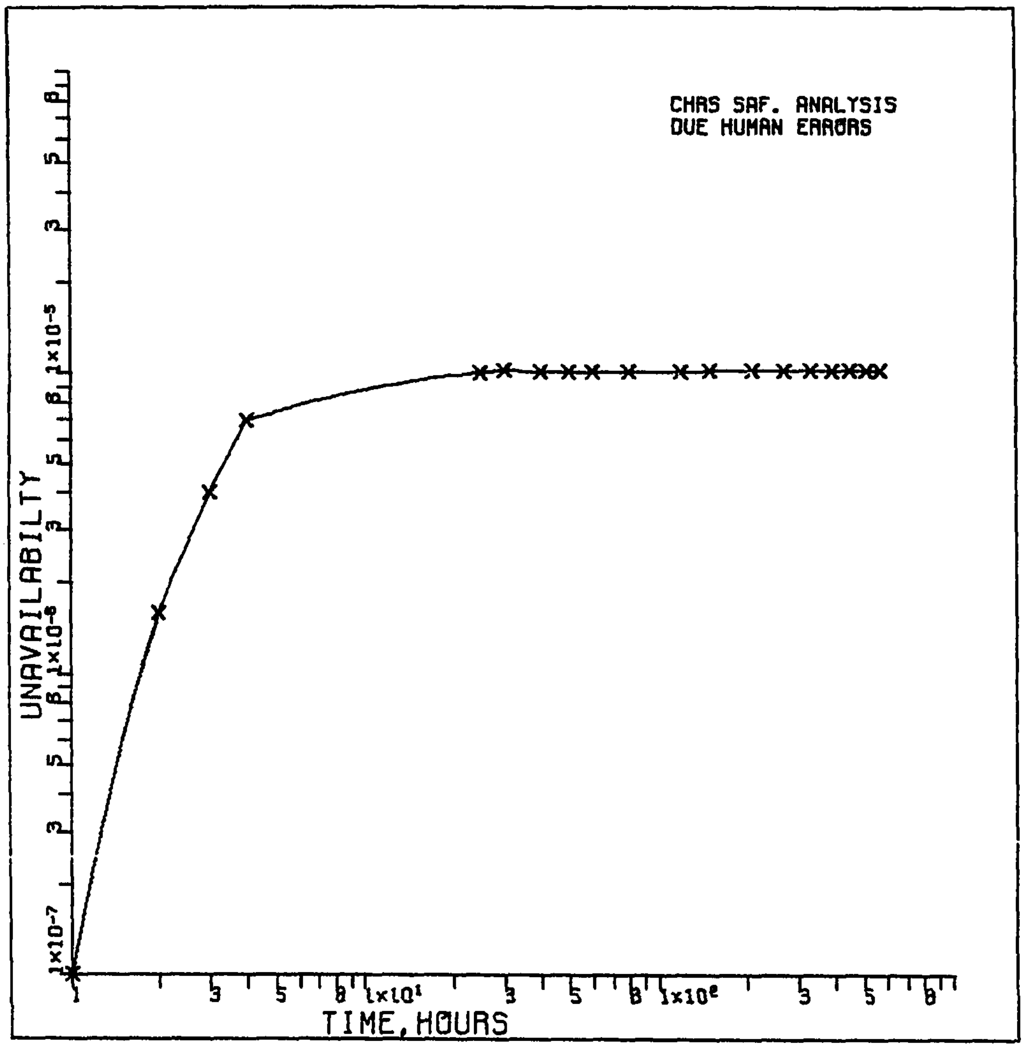

Figure 8.22. Unavailability of the CHRS using WASH-1400 data (case 1)

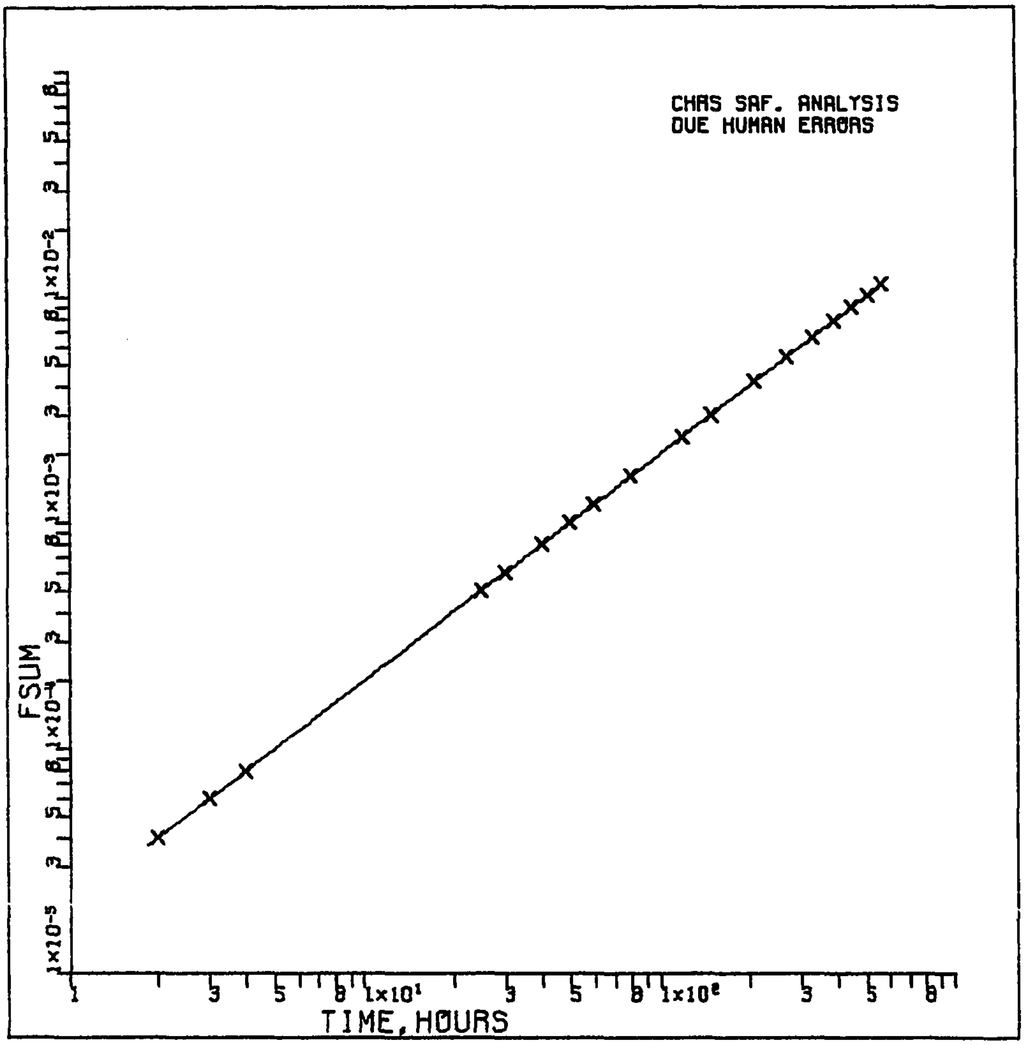

Figure 8.23. Probability of failure of one or more components at time t for the CHRS using WASH-1400 (case 1)

8.5.3.2. Case 2: LERs Having obtained the minimal cut sets from the PREPS, the KITT-1 codes were then run to obtain the probability characteristics associated with "three of four HE in the CHRS not removing sufficient spray fluid," using the fault tree in Fig. 8.18. The results from KITT-1 are shown in Appendix F.

Some of the system differential and integral characteristics resulted from KITT-1 codes run are summarized below in Table 8.20 and plotted in Figs. 8.24 and 8.25, where the program output symbols are defined in Section 8.4.1.

Table 8.20. Some system characteristics resulted from KITT-1 code run for CHRS using LER data (case 2)

T(hours)	Unavailability (Q) (per demand)	Probability of one or more failure to time t (FSUM)
0.0	0.0×10^{-5}	--
30.0	1.008×10^{-5}	5.99×10^{-4}
60.0	1.015×10^{-5}	1.19×10^{-3}
90.0	1.017×10^{-5}	1.79×10^{-3}
150.0	1.018×10^{-5}	2.99×10^{-3}
210.0	1.019×10^{-5}	4.19×10^{-3}
270.0	1.020×10^{-5}	5.39×10^{-3}
300.0	1.021×10^{-5}	5.98×10^{-3}
330.0	1.021×10^{-5}	6.58×10^{-3}
360.0	1.022×10^{-5}	7.18×10^{-3}
420.0	1.022×10^{-5}	8.37×10^{-3}
480.0	1.022×10^{-5}	9.56×10^{-3}
540.0	1.022×10^{-5}	1.07×10^{-2}
570.0	1.022×10^{-5}	1.13×10^{-2}

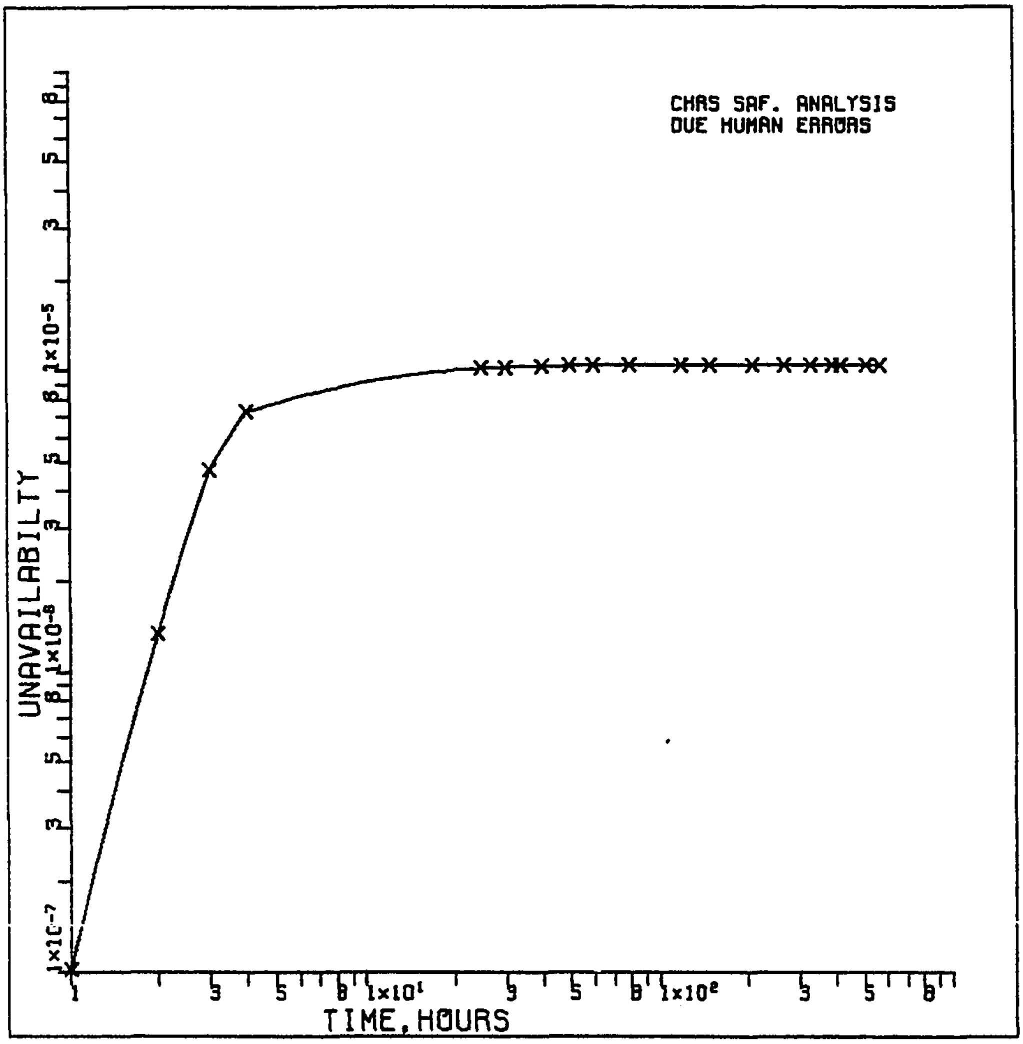

Figure 8.24. Unavailability of the CHRS using LER data on human errors (case 2)

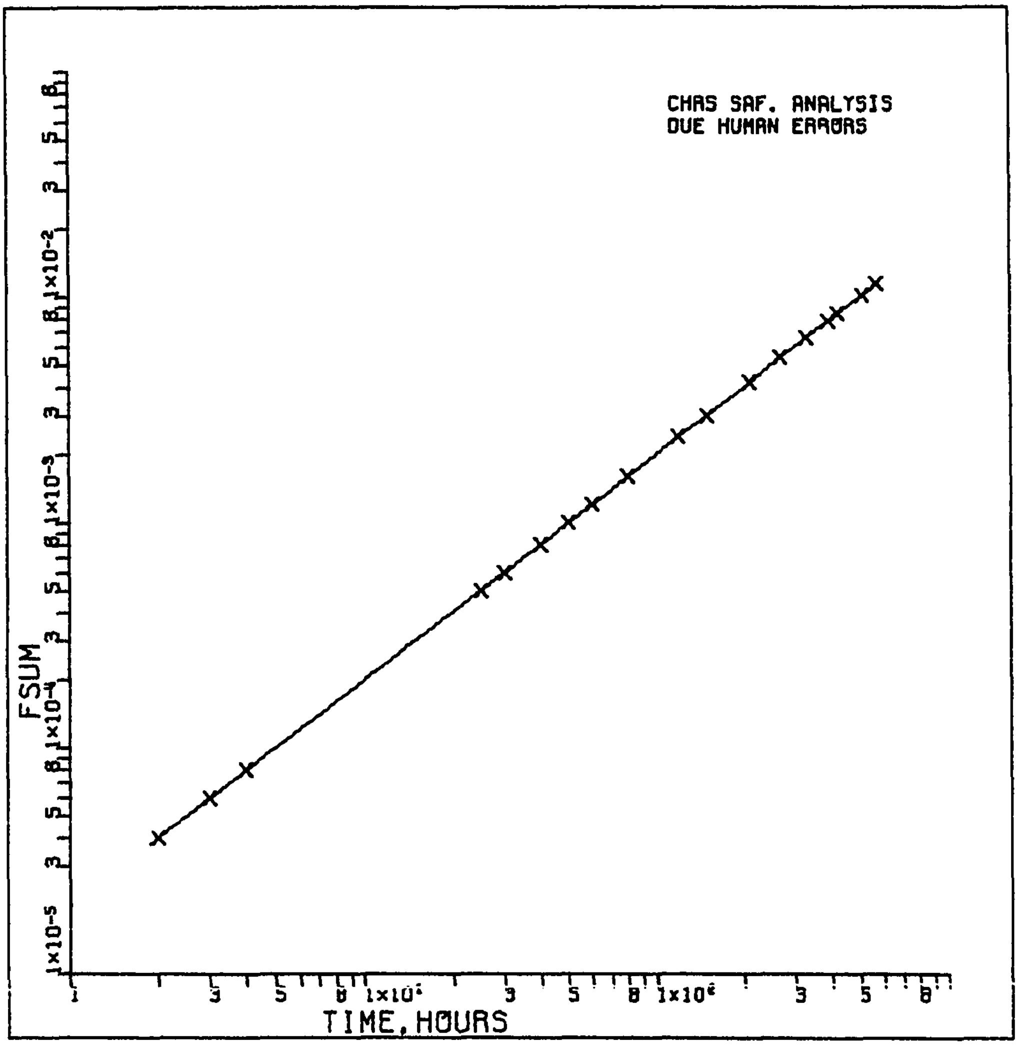

Figure 8.25. Probability of failure of one or more components at time t using LER data (case 2)

8.5.3.3. Case 3: NUREG/CR-1278 Having obtained the minimal cut sets from the PREPS, the KITT-1 codes were then run to obtain the probability characteristics associated with, "three of four HE in the CHRS not removing sufficient heat from spray fluid," using the fault tree in Fig. 8.18. The results from KITT-1 are shown in Appendix F.

Some of the system differential and integral characteristics resulted from KITT-1 codes run are summarized below in Table 8.21 and plotted in Figs. 8.26 and 8.27 where the program output symbols are defined in Section 8.4.1.

Table 8.21. Some system characteristics resulting from KITT-1 code run for CHRS using data from NUREG/CR-1278 (case 3)

T(hours)	Unavailability (Q) (per demand)	Probability of one or more failure to time t (FSUM)
0.0	0.0	--
30.0	1.027×10^{-5}	6.00×10^{-4}
60.0	1.039×10^{-5}	1.20×10^{-3}
90.0	1.043×10^{-5}	1.80×10^{-3}
150.0	1.044×10^{-5}	2.99×10^{-3}
210.0	1.045×10^{-5}	3.99×10^{-3}
270.0	1.046×10^{-5}	4.19×10^{-3}
300.0	1.047×10^{-5}	5.39×10^{-3}
330.0	1.048×10^{-5}	5.98×10^{-3}
360.0	1.048×10^{-5}	6.59×10^{-3}
420.0	1.048×10^{-5}	8.38×10^{-3}
480.0	1.048×10^{-5}	9.37×10^{-3}
540.0	1.048×10^{-5}	1.08×10^{-2}
570.0	1.048×10^{-5}	1.14×10^{-2}

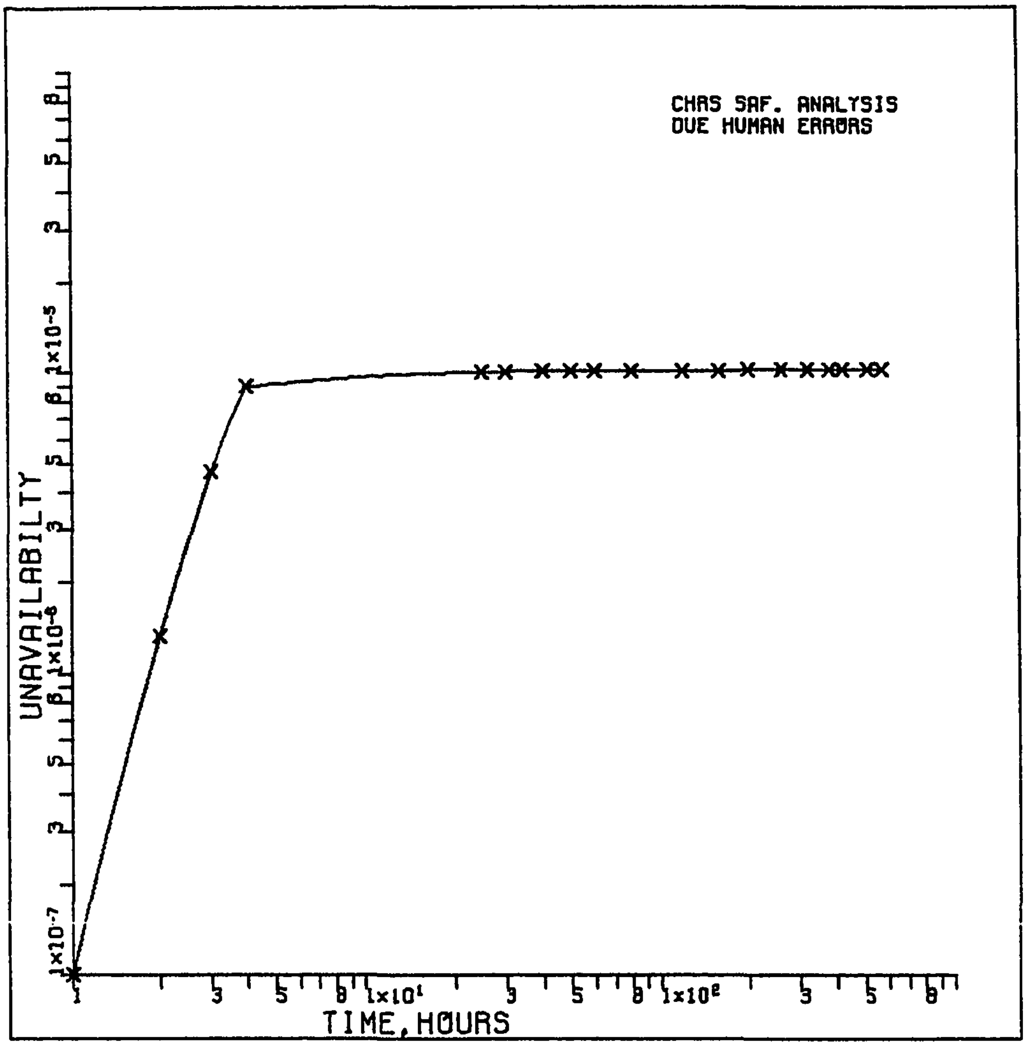

Figure 8.26. Unavailability of CHRS using NUREG/CR-1278 data on human errors (case 3)

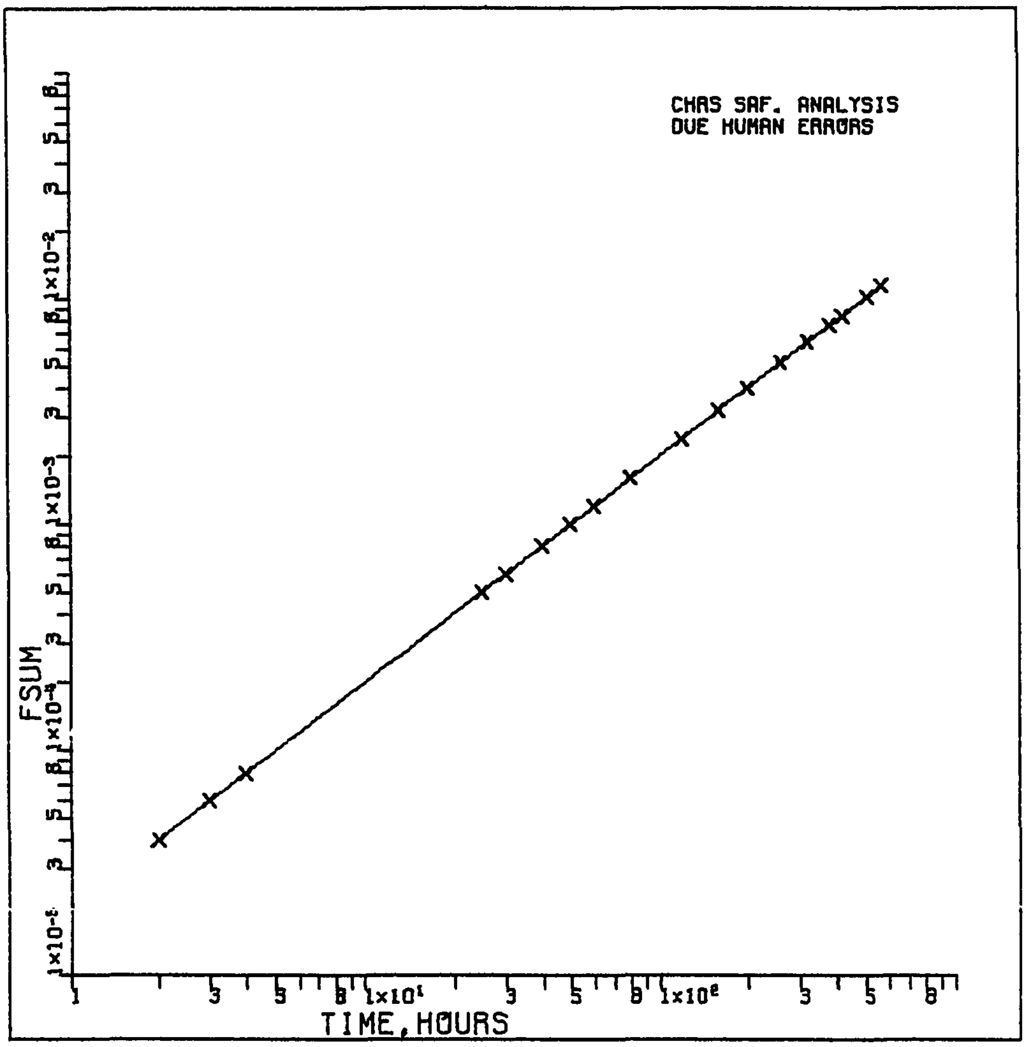

Figure 8.27. Probability of failure of one or more components at time t for the CHRS using human error data from NUREG/CR-1278 (case 3)

8.5.3.4. Discussion of the results The CHRS unavailability, Q, and the probability of one or more failure at operation time t, FSUM, for the three cases described in section 8.3.3 are presented in Figs. 8.22 through 8.27. By reviewing these figures, it can be noted that the Q for the three cases increases as the operation time t increases ($t = 0$ to 570 hours), but, as the operation time reaches approximately 40 hours, the Q becomes flat. The reason, as pointed out previously, for that is that this time (i.e., 40 hours) corresponds to the average repair time for the components presented in Tables 8.14 through 8.16. More discussion about this matter is reviewed in section 8.4.5. The FSUM increases as the operation time increases.

The results from the KITT-1 codes output for the three cases described in section 8.3.3 are summarized in Table 8.22.

Table 8.22. KITT-1 output results

Source of the data	Unavailability, Q, at time $t = 60$ hours	Probability of one or more failure at time $t = 60$ hours
WASH-1400	1.01×10^{-5}	1.19×10^{-3}
NUREG/CR-1278	1.04×10^{-5}	1.20×10^{-3}
LERs	1.01×10^{-5}	1.19×10^{-3}

The results in this table show that the unavailability of the CHRS, Q, and the FSUM are higher when the NUREG/CR-1278 are used as a source of data. For the other two cases (i.e., the LERs and WASH-1400), the Q and the FSUM are approximately equal.

9. SUMMARY AND CONCLUSIONS

Operation history of nuclear power plants (NPPs) shows that human errors play an important role in the reliability and safety of NPPs. Human reliability analysis is usually performed to estimate the influence of human errors on the unavailability of various safety systems of NPPs.

The analysis presented here is the first attempt at using gross operator error rates estimated from information given in LERs to analyze fault trees developed for those systems involved in the S_2C accident sequence. Fault tree analysis (FTA) is commonly used in probabilistic risk assessment (PRA) and reliability analysis. The S_2C sequence is selected for this study because this sequence makes a significant contribution to risk. The sequence could be initiated by a small LOCA (S_2). There are a number of systems involving it. Those systems are the CSIS, CSRS, CHRS and SHAS.

In earlier reactor safety studies, the operator error rates used in FTA have been estimated from other industries. Human actions are often not included in FTA. The obvious advantage of the analysis performed here is the fact that it is based on human failure data from operating reactor rather than on the history of other industries.

The error rates derived from the LERs are estimated for failure modes of valves in those systems involved in the S_2C sequence. The operator error rates estimated here are for a broad class of valves and valve operating environment. There was no attempt made to calculate specific error rates for particular valve classes or sizes, for the medium transmitted by the valve (water or steam), or for the environment in which the valve operates.

There are two related areas of concern in using the LERs to estimate the operator error rates. The first concern is whether all failures of a given severity are actually reported. The second concern is one's ability to reasonably estimate the population of valves with which the failures are associated. The error rates estimated here should, therefore, only be interpreted to order of magnitude precision. More refined analysis and information are required before more precise error rates can be estimated.

A comparison has been made between data estimates from LERs and error rates given in the Handbook of Human Reliability Analysis with Emphasis on NPP Applications (NUREG/CR-1278) and in the Reactor Safety Study (WASH-1400). More discussion of this comparison is given in Section 7.5.

The unavailabilities of the systems involved in the S_2C accident sequence due to human errors were estimated using LERs data and the results were compared with the values given in WASH-1400 (1). More discussion of the results and the comparison are given in Section 6.2.4.

From the FTA of the CSIS and the CHRS, the following observations are made:

(1) The unavailability of the CSIS, Q, and the probability of one or more failures at time t, FSUM, are calculated using data from WASH-1400 (case 1), the calculated data from LERs (case 2), and the calculated data from NUREG/CR-1278 (case 3). The results show that the Q and the FSUM are lower when the LERs are used as a source of data. More discussion of the results was presented in Section 8.4.5.

(2) The CHRS unavailability, Q, and the probability of one or more failures at time t, FSUM, are calculated using data from the three cases. The results show that the Q and the FSUM are higher when the NUREG/CR-1278 are used as a source of data. But for the other two cases (case 1 and 2), the Q and the FSUM are equal. More discussion of the results was given in Section 8.5.3.4.

(3) It is felt that the following reasons are possibly the cause for the results obtained: (a) There is a lack of human actions on the CSIS and on the CHRS fault trees, and (b) in those fault trees the human events/occurrences were treated as a primary

event. As was pointed out, a primary event is the event which doesn't need further development in the fault tree.

From the sensitivity analysis, the following observations are made:

(1) A sensitivity analysis was made here to show how sensitive the unavailability, Q, and the probability of one or more failure, FSUM, to those human events found in the CSIS fault tree (CP-A1 and CP-A4).

(2) As the operator error rates increase, the Q and the FSUM increase and as the operator error rate reaches 10^{-5} error/hour, they increase very rapidly. This is because human failures are dominant over component failures. More discussion on this is presented in Section 8.4.5.

(3) As can be seen from the sensitivity analysis results (Figs. 8.13 through 8.16), no significant changes in the Q and in the FSUM of the CSIS were found by comparing the two cases considered in the analysis. These two cases are: (a) Keeping the error rate for the human event represented by CP-A1 in the fault tree constant and slightly varying it for the human event represented by CP-A4 in the fault tree, and (b) keeping the

error rate for the human event represented by CP-A4 constant and slightly varying it for CP-A1.

(4) It can be concluded from the analysis that the Q and the FSUM are sensitive to the two human events represented by CP-A1 and CP-A4 in the fault tree.

10. RECOMMENDATION FOR FURTHER WORK

The accident at TMI has forced the nuclear industry to acknowledge a badly neglected aspect of human equation in NPP safety. The industry now appears to recognize the importance of operator selection, training, motivation, and licensing, and the need to design a system from the point of view of communication, information retrieval, record keeping, and human factors psychology. It is suggested that perhaps using reactor simulators in training could best fulfill the need in these areas. Then error rates during training could be carefully documented and related to such factors as operator age, experience, training time, and others.

From the results of this research, the following remarks are made:

(1) From the foregoing, it is apparent that efforts are needed to collect both objective and subjective human performance data applicable to NPP tasks. The objective data bank will consist of error rates that have been recorded along with the best of measures of PSFs associated with the errors. An example of this is presented in section 2. The subjective data bank will consist of expert opinions quantified by psychological scaling techniques.

(2) The analysis required before more precise operator error rates can be estimated using LERs is to improve the present methodology used in the calculation of the error rates and the unavailabilities. It is suggested that perhaps time-dependent unavailability analysis could solve part of this problem. This will require additional mathematical treatment and data.

(3) The information needed before more precise operator error rates can be estimated using LERs is the population and the critical hours of valves with which the failures are associated in those systems involved in the S_2C sequence. From the foregoing, it is apparent that efforts are needed to collect such data and make them available.

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13. APPENDIX A: CHARACTERIZATION OF OPERATOR "ERRORS" FROM ANALYZED LICENSEE EVENT REPORTS (LERs)

The following tables are based on the analysis of operator-related Licensee Event Reports (LERs). The information matrix is designed to facilitate the characterization of operator "errors" and the identification of trends.

For each event, the following information is provided:

(1) LER reference number (RN);

(2) Plant name and docket number;

(3) Event and report dates;

(4) Systems and components involved/affected (codes used for systems and components identification are given in Tables 13.1 and 13.2);

(5) Failure mode (Tables 13.3 and 13.4 give the code used for failure modes);

(6) Type of personnel involved (Table 13.5 gives the code used in identifying personnel and their jobs and responsibilities);

(7) Duration till discovery and means of discovery (Tables 13.6 and 13.7 provide the code used to identify "the method of discovery" and the "cue of discovery"); and

(8) Plant status (Table 13.8 gives the code used for specifying plant status).

A summary of a sample of collected data characterizing operator-related events is provided in Table 13.9.

Table 13.1. Code used for reactor systems matrix

Standard generic code	System description
	Reactor
RA	Reactor Vessel Internals
RB	Reactivity Control Systems
RC	Reactor Core
	Reactor Coolant System & Connected Systems
CA	Reactor Vessels & Appurtenances
CB	Coolant Recirculation Systems & Controls
CC	Main Steam Systems & Controls
CD	Main Steam Isolation Systems & Controls
CE	Reactor Core Isolation Cooling Systems & Controls
CF	Residual Heat Removal Systems & Controls
CG	Reactor Coolant Cleanup Systems & Controls
CH	Feedwater Systems & Controls
CI	Reactor Coolant Pressure Boundary Leakage Detection Systems
CJ	Other Coolant Subsystems & Their Controls
	Engineered Safety Features
SA	Reactor Containment Systems
SB	Containment Removal Systems & Controls
SC	Containment Air Purification & Cleanup Systems & Controls
SD	Containment Isolation Systems & Controls
SE	Containment Combustible Gas Control Systems & Controls
SF	Emergency Core Cooling Systems & Controls
SG	Control Room Habitability Systems & Controls
SH	Other Engineered Safety Feature Systems & Their Controls
	Instrumentation and Controls
IA	Reactor Trip Systems
IB	Engineered Safety Feature Instrument Systems
IC	Systems Required for Safe Shutdown
ID	Safety Related Display Instrumentation
IE	Other Instrument Systems Required for Safety
IF	Other Instrument Systems Not Required for Safety

Table 13.1. (Continued)

Standard generic code	System description
	Electric Power Systems
EA	Offsite Power Systems & Controls
EB	AC Onsite Power Systems & Controls
EC	DC Onsite Power Systems & Controls
ED	Onsite Power Systems & Controls (Composite AC & DC)
EE	Emergency Generator Systems & Controls
EF	Emergency Lighting Systems & Controls
EG	Other Electric Power Systems & Controls
	Fuel Storage and Handling Systems
FA	New Fuel Storage Facilities
FB	Spent Fuel Storage Facilities
FC	Spent Fuel Pool Cooling & Cleanup Systems & Controls
FD	Fuel Handling Systems
	Auxiliary Water Systems
WA	Station Service Water Systems & Controls
WB	Cooling Systems for Reactor Auxiliaries & Controls
WC	Demineralized Water Make-up Systems & Controls
WD	Potable & Sanitary Water Systems & Controls
WE	Ultimate Heat Sink Facilities
WF	Condensate Storage Facilities
WG	Other Auxiliary Water Systems & Their Controls
	Auxiliary Process Systems
PA	Compressed Air Systems & Controls
PB	Process Sampling Systems
PC	Chemical, Volume Control & Liquid Poison Systems & Controls
PD	Failed Fuel Detection Systems
PE	Other Auxiliary Process Systems & Their Controls
	Other Auxiliary Systems
AA	Air Conditioning, Heating, Cooling & Ventilation Systems & Controls

Table 13.1. (Continued)

Standard generic code	System description
AB	Fire Protection Systems & Controls
AC	Communication Systems
AD	Other Auxiliary Systems & Their Controls
	<u>Steam and Power Conversion Systems</u>
HA	Turbine-Generators & Controls
HB	Main Steam Supply System & Controls (Other than CC)
HC	Main Condenser Systems & Controls
HD	Turbine Gland Sealing Systems & Controls
HE	Turbine Bypass Systems & Controls
HF	Circulating Water Systems & Controls
HG	Condensate Clean-up Systems & Controls
HH	Condensate and Feedwater Systems & Controls (Other than CH)
HI	Steam Generator Blowdown Systems & Controls
HJ	Other Features of Steam & Power Conversion Systems (Not included elsewhere)
	<u>Radioactive Waste Management Systems</u>
MA	Liquid Radioactive Waste Management Systems
MB	Gaseous Radioactive Waste Management Systems
MC	Process & Effluent Radiological Monitoring Systems
MD	Solid Radioactive Waste Management Systems
	<u>Radiation Protection Systems</u>
BA	Area Monitoring Systems
BB	Airborne Radioactivity Monitoring Systems
XX	<u>Other Systems</u>
ZZ	<u>System Code Not Applicable</u>

Table 13.2.a. Code used for "mechanical component" identification

Code	Component	Code	Component
BL	Blower/fan	RU	Refrigeration unit
		RW	Rod worth minimizer
CT	Cabinet		
CM	Cam	SH	Shock absorber/hydraulic
CL	Clamp	SB	Snubber
CC	Cooler/Chiller	SA	Sluice gate
CN	Condenser	SG	Steam generator
CR	Control Rod	SN	Strainer
CD	Control rod drive unit	SE	Subtree
CP	Cover plate	SU	Sump
CP	Damper	TR	Tank, accumulator
DZ	Demineralizer	TJ	Tank, boron injection
DG	Diesel generator	TB	Tank, boric acid storage
DH	Door/hatch	TA	Tank, chemical addition
DW	Drywell	TD	Tank, condensate storage
DI	Duct	TC	Tank, core flood
		TU	Tank, fuel
FS	Filter or strainer	TG	Tank, refueling water storage
FT	Fitting	TS	Tank, surge
FG	Flange	TX	Tank, other
FE	Fuel element/assembly	TQ	Tendon
		TV	Tubing
GB	Gas bottle	TI	Turbine
GK	Gasket		
		VC	Valve, check
HE	Heat exchanger	VE	Valve, explosive operated
		VH	Valve, hydraulic operated
LN	Line	VM	Valve, manual
LK	Linkage	VO	Valve, motor operated
		VP	Valve, operator
NZ	Nozzle	VU	Valve, pneumatic operated
		VR	Valve, relief
OR	Orifice	VS	Valve, safety
		VF	Valve, safety-relief
PP	Pipe	VD	Valve, solenoid operated
PJ	Pipe gap/joint	VK	Valve, stop check
PO	Pool	VX	Valve, unknown
PV	Pressure vessel	VV	Valve, vacuum relief
PZ	Pressurizer	VT	Vent
PM	Pump		
		WO	Well, other
		WW	Wetwell, Torus

Table 13.2.b. Code used for "electrical component" identification

Code	Component	Code	Component
AL	Alarm	PR	Potentiometer
AM	Amplifier	PB	Pushbutton
AZ	Analyzer		
AN	Annunciator	RM	Radiation monitor
		RC	Recorder
BY	Battery/DC power supply	RG	Regulator
BC	Battery charger	RY	Relay
BI	Bistable	RS	Relay or switch contact
BS	Bus	RT	Resistor, temperature device
CA	Cable	SO	Signal comparator
CB	Circuit breaker	SC	Switch, control
CH	Clutch	SF	Switch, flow
CD	Coil	SD	Switch, ground
		SV	Switch, level
DT	Detector	SL	Switch, limit
DI	Dial	SM	Switch, manual
DR	Diode or rectifier	SP	Switch, pressure
		SR	Switch, reset
FD	Film badge/dosimeter	ST	Switch, temperature
FU	Fuse	SQ	Switch, torque
		SX	Switch, unknown
GE	Generator		
		TZ	Terminal board
HT	Heat tracing element	TO	Thermal overload
HG	Heating element	TH	Thermostat
		TM	Timer
IP	Incore probe	TN	Transformer, Current
IM	Input module	TP	Transformer, potential
IO	Instrumentation (others)	TW	Transformer, power (or control)
IR	Inverter (solid state)		
		TF	Transformer, flow
JP	Jumper	TL	Transformer, level
		TE	Transformer, pressure
LT	Light	TT	Transformer, temperature
LA	Lightening arrestor		
		WR	Wire
MN	Monitor, other than radiation	00	Event
MO	Motor		
MS	Motor starter		

Table 13.3. Code used for "failure mode"

Category	Failure mode
1	Action Being Omitted The action can be a step in the procedure or written/oral instruction.
2	Action Being Committed Incorrectly
3	Inadvertence In this category, the personnel commits an action which should not have been taken.
4	Communication If there are more than one personnel involved in the event, the failure mode will be under this category. Problems with communication may be within one shift or between different shifts. Also, they may be between two or more crews. The failure mode under this category will be coded as "4CC".
5	Personnel/Training Under this category we will put all human errors that are related to: (i) Lack of experience/training; (ii) Psychometric parameters. Failure modes such as: Misidentifications (code 5 MD), Misinterpretation (code 5 MT), Misjudgment (code 5 MJ), Slow/fast response (code 5 CR, 5 FR), Procedure unfamiliarity (5 PN), and Lack of experience (5 LE) will be under this category.
6	Procedure Inadequacy/Deficiency This will be coded as "6 PD".

Table 13.4. "Most repetitive action in operations" events

Action	Code	Action	Code
Adjust	AD	Open	OP
Actuate	AC	Operate	OR
Add	AD	Place in service	PS
Align	AL	Position	PN
Calculate	CI	Procedure inadequacy	PI
Calibrate	CB	Misjudge	MJ
Check/verify	CH	Remove from service	RS
Close	CL	Record	RC
Connect	CN	Release	RL
Control	CR	Report	RP
Deenergize	DG	Reset	RT
Energize	EG	Return to service	RN
Fill	FL	Review	RV
Follow procedure	FP	Sample	SM
Insert	IN	Slow response	SR
Inattention	IA	Start	ST
Lock	LO	Secure	SC
Log	LG	Tag	TG
Maintain	MT	Tighten	TN
Monitor	MR	Test	TS
No response	NR	Unlock	UL
Notify	NO	Verify	VF
Observe	OB	Withdraw	WD

Table 13.5. Code used for "personnel" (job and responsibility)

Code	Personnel	Responsibility
	<u>Operations Staff</u>	
SS	Shift Supervisor	Responsible for the station during an assigned work shift.
SCO	Senior Control Operator	Instructs, trains, and assigns work to personnel engaged in controlling the operation of reactor-generator units and associated equipment.
CO	Control Operator	Actual operation and control of the reactor turbine generator units and associated equipment.
EO	Equipment Operator	Assists the control operator on shift. His responsibility is operation and inspection of individual equipment and the operation of the radwaste systems on a rotating basis during normal plant shutdown.
EA	Equipment Attendant	Works as directed by operations personnel to operate equipment and systems in areas of water treatment, oil cleaning, and fuel handling. He works with the relief shift supervisor on fuel handling, radwaste, relief duties and unusual problems.
	<u>Technical Staff</u>	
RE	Reactor Engineer	Responsible for the safe, efficient performance of the reactor and performs nuclear physics. Calculations as required to assure proper fuel management and that thermal limitations are not exceeded.
PPE	Power Plant Engineer	Responsible for determining station performance, the establishment of efficient operating procedures and, in conjunction with the reactor engineers, the most efficient utilization of fuel.

Table 13.5. (Continued)

Code	Personnel	Responsibility
CE	Chemical Engineer	Directs the chemical and radiochemical programs of the plant and environs.
RPE	Radiation Protection Engineer	Directs radiation protection programs.
GC	Graduate Chemist	Has the responsibility for the day-to-day direction of the chemical technicians and the assurance that plant chemistry is maintained within license limits.
CT	Chemical Technician	Prepares and analyzes test specimens, assembles materials and equipment, and makes the necessary analysis of data.
HP	Health Physicist	Responsible for daily direction of radiation protection technicians and the implementation of the radiation protection program to plant license standards.
RPT	Radiation Protection Technician	Measuring and reading through routine radiation surveys, he implements the plant radiation protection program as required by approved procedure.
	<u>Maintenance Staff</u>	
M	Instrument Foreman Instrument Technicians Electrical Foremen Electricians Mechanical Foremen Mechanics Welders Helpers Storekeepers Stockmen	Instrument, electrical, and mechanical foremen are required to direct and be responsible for the calibration, maintenance, and operation of equipment in their respective areas of experience and training, and to oversee the efforts of technicians, electricians, and mechanics serving under them.

Table 13.6. Code used for method of discovery

Code	Discovery method
A	Operational event - any event not included in the codes below.
B	Routine test/inspection - surveillance test - previous maintenance test - annual inspections - etc.
C	Special test/inspection - nonroutine tests.
D	External source - such as notification from NRC, sister licensee, vendor, A/E - etc.
Z	Item not applicable

Table 13.7. Code used for "cue of discovery"

Code	Cue description
OVD	1. Observation of unannunciated displays Nonannunciated displays include: o Meters o Digital displays o Chart recorders o Indicator lights o Graphs Examples are: o Valve position indicators (open-close) o Control rod position indicators (in notches) o Temperature, pressure, level, volume, concentration, and activity indicators
AD	2. Annunciated displays Examples: o Low/high level alarm o High activity alarm o Low flow alarm
OWI	3. Observation while walk-in Usually this code will be used for walk-in outside the control room (e.g. auxiliary building, DT building, etc.) Examples: o Noticing water on the floor of the auxiliary building o Noticing tank overflowing o Hearing sound of air blowing in DG room
ROL	4. Review operation logs Examples: o Operation data o Monitor charts o Power recorder charts o Plant status
RSL	5. Review survey/test logs Examples: o Test completion and results o Test due and intervals

Table 13.7. (Continued)

Code	Cue description
	o Routine log review o Jumper log review o Sampling schedule (discharge, viz. sampling)
RI	6. Random inspection Examples: o Relays block after survey o Routine operator patrol in control room o Valve line-up checks
SD	7. Severe damage Examples: o Water hammer
SI	8. Safety injection
RT	9. Reactor trip
RPL	10. Review release log
PI	11. Problem investigation
CR	12. Calculated results

Table 13.8. Code used for "plant status"

Code	Status
A	Under construction
B	Preoperational, S/U or power ascension tests (in progress)
C	Routine S/U operations
D	Routine S/D operations
E	Steady state operations
F	Load changes during routine power operation
G	S/D (hot or cold) except refueling
H	Refueling
X	Others (including special tests, emergency S/D operations, etc.)
Z	Item not applicable

Table 13.9. Analyzed information matrix for characterizing operator errors reported in the LERs

	S.N.	R.N.	Plant: Name	Plant: Dock	Event Date	Report Date	System: Involved	System: Affected	Component: Involved	Component: Affected	Failure Mode	Personnel	Duration	Discovery: Cue	Discovery: Method	Plant: Power	Plant: Mode	Remarks:
1	002	000009	IP1	003	032573	040573	PC	XX	VX	PM	20P	CO	32D	OUD	B	000	G	<u>Improper/Open (opened</u> too rapidly).
2	003	000939			032874	040574	MA	WC	VM	FS	1CL	EO	15M	OUD	A	080	E	<u>Left Partially Open.</u>
3	004	010268			061274	062174	MA	WC	VM	FS	1CL	EO	5M	OUD	A	090	E	<u>Did Not Close.</u>
4	005	010322			062774	070574	MA	XX	TX	XX	3RL	CO	Z	ROL	A	095	E	<u>Indavertent Release</u> (without permit).
5	007	002379	IP2	247	091172	101172	CC	XX	VM	XX	2CL	CO	Z	OUD	C	0	A	<u>Improper Closure</u> (should be opened).
6	008	001156			051973	052973	SF (HPIS)	XX	VO	AC	1VF	CO	Z	OUD	C	0	A	<u>Did Not Verify</u> (valve position).
7	009	000078			012574	020874	RB	XX	CR	XX	2CT	CO	Z	OUD	C	0	A	<u>Improper Calculation</u> (criticality condition).
8	010	010625			083074	090974	FC	XX	TG	XX	1MT	CO	Z	OUD	A	0	D	<u>Did Not Monitor</u> (low level).
9	011	015920			080576	091576	FC	SF	VM	PM	10P	CO	Z	OUD	A	0	H	<u>Did Not Open</u> (during test).
10	012	017273			121276	031677	RB	XX	OO	XX	5MD	CO	10M	OUD	A	068	C	<u>Misunderstanding</u> (requirements when axial $\Delta\phi$ is outside target band).
11	013	016743			122776	012677	IA	ID	BI	IO	3AC	CO	Z	RI	A	020	C	<u>Inadvertent Actuation.</u>
12	014	019242			082177	092977	PC	XX	TA	XX	2AD	CO	Z	OWI	A	000	C	<u>Improper Addition Rate</u>.
13	015	014604	IP3	286	042976	052576	SB	XX	VX	PM	2AL	CO	Ø	OUD	A	000	B	<u>Misalignment</u> (during test).
14	016	010319	KE1	305	070974	071974	CB	XX	VM	XX	1CL	CO	Z	OWI	A	0	G	<u>Left Open.</u>
15	017	010929			092074	100174	MC	XX	SC	RM	2PN	Cu	Z	OUD	A	0	G	<u>Mispositioning</u>.
16	019	015635			013175	031475	PC	XX	TA	XX	1MR	CO	Ø	AD	A	073	E	<u>Did Not Monitor</u> (high level).
17	020	013669			110575	111475	EE	XX	SC	DG	2PN	CO	Ø	OUD	A	008	C	<u>Mispositioning</u> (during test).

Table 13.9. (Continued)

			Plant				System		Component					Discovery		Plant		
	S.N.	R.N.	Name	Dock	Event Date	Report Date	Involved	Affected	Involved	Affected	Failure Mode	Personnel	Duration	Cue	Method	Power	Mode	Remarks:
18 Cont.	021	014240			022076	032176	SA	XX	VO	XX	2CL	EO	Z	OUD	B	000	H	Improper closure (overtorqued to prevent leakage).
19	022	014672			051876	052876	WO	XX	OO	XX	5MJ	CO	Z	OUD	A	099	E	Misjudgement (time to automatic regeneration sampling was not performed.)
20	023	015295			081376	081376	PC	XX	VM	XX	1CL	CO	Z	OUD	A	099	E	Left Open (After release).
21	024	016545			120576	123076	WD	XX	SU	XX	1SM	CT	170	RSL	B	098	E	Did Not Sample (oversight).
22	025	017824			052277	060677	WB	XX	VM	PM	1OP	EO	3H	RI	A	100	E	Did Not Open (Distraction by other duties).
23	026	018282			070577	071977	CI	XX	SC	RM	1PN	EO	12H	RI	A	100	E	Left in Wrong Position (after surveillance.)
24	027	019064			071677	081577	WC	XX	VX	XX	2AL	CO	Z	DUD	B	100	E	Misalignment.
25	028	012937	MY1	309	061975	062575	SF	XX	VO	XX	1VF	CO	Z	OUD	A	000	C	Did Not Verify (valve position).
26	029	002323			120272	121472	CC	XX	RC	VO	2CN	CO	Ø	RT	A	Z	Z	Improper Connection.
27	030	002063			120872	121872	SF	XX	TX	XX	1MR	CO	Z	OUD	A	000	G	Did Not Monitor (low pressure).
28	031	015731			091676	092076	SA	XX	VX	XX	1CL	EO	Z	OWI	A	060	E	Left Open (after maintenance).
29	032	013187	MI2	336	081275	082075	FC	XX	VM	XX	1CL	CO	Z	RI	B	Ø	B	Did Not Close (during draining).
30	033	013380			090575	100175	CJ	XX	OO	XX	5MT	CO	Z	OUO	B	Ø	B	Misinterpretation (information from Chemistry Dept. O_2concentration vis RC temp.)
31	034	013659			102075	111775	RB	XX	ZZ	XX	1TS	CO	Z	OUD	C	Ø	B	Did Not Test (requirements were overlooked in review of proc. by operating and test personnel).
32	035	014164			012876	022476	EE	XX	DG	XX	1TS	CO	390M	RSL	B	Ø	B	Did Not Test (misinterpretation of Test performance on out-of-service components).
33	036	014164			012876	022476	EE	XX	DG	XX	1TS	CO	3H	RSL	B	Ø	B	Did Not Test (misinterpretation of Test performance on out-of-service component).
34	037	015578			080476	090376	SF	RB	TX	XX	1FL	CO	Z	OUD	B	100	E	Did Not Fill (in time).

Table 13.9. (Continued)

	S.N.	R.N.	Plant: Name	Plant: Dock	Event Date	Report Date	System: Involved	System: Affected	Component: Involved	Component: Affected	Failure Mode	Personnel	Duration	Discovery: Cue	Discovery: Method	Plant: Power	Plant: Mode	Remarks:
35 Cont.	038	016721			121976	011877	SF	CB	VO	TJ	1CL	CO	Z	AD	Z	Ø	D	Did Not Close (upon receiving SIT low level).
36	039	001002	OE1	269	040573	050473	SB	XX	VO	XX	2CL	EO	Z	OUD	B	Ø	G	Improper closure (Overtorqued to prevent leakage).
37	040	001004			050873	051873	SB	XX	CB	PM	1VF	CO	82H	OUD	B	015	B	Did Not verify (jacking out/in).
38	041	000222			062673	073173	WB	XX	VO	XX	1RN	EO	Z	OUD	B	Ø	B	Did Not Return To Service (pin that prevents auto operation not removed after test.)
39	042	000417			100573	101673	RB	XX	CR	XX	2WD	CO	Ø	OUD	A	095	E	Improper withdrawal (withdrawal limits exceeded).
40	043	000401			100773	101773	SF	XX	CB	VO	1VF	CO	Z	RI	A	Ø	G	Did Not Verify (locking close/open).
41	044	000401			100773	101773	SF	XX	CB	VO	1VF	CO	Z	RI	A	Ø	G	Did Not Verify (locking close/open).
42	045	000621			120873	122073	SB	XX	CB	VO	1VF	CO	15M	OUD	A	Z	Z	Did Not Verify (racking out/in).
43	046	010098			032074	032874	PC	XX	OO	XX	5MD	CO	Ø	OUD	A	090	E	Misunderstanding (T.S. forbids changing boron concentration above 80% power.)
44	047	010052			042574	050674	MA	XX	VH	TC	3OP	EO	19M	AD	A	075	E	Inadvertent Open (close proximity).
45	048	010309			051374	052374	MB	XX	RH	XX	1RN	EO	75M	OUD	A	Ø	G	Did Not Return to Service (after calibration).
46	049	010562			081674	083074	MB	XX	LH	TX	1OB	CO	15M	AD	A	Ø	E	Failure to Observe (moisture in sight glass.)
47	050	011002			100274	102274	SF	XX	ZZ	XX	1FP	CO	Z	RSL	A	Ø	E	Did Not Follow Procedure (precriticality checkoff procedure performed out of sequence.)
48	051	011000			101274	102574	SF	XX	VO	PM	1VF	EO	Z	OWI	A	Ø	F	Did Not verify (valve position).
49	052	012868			051275	061275	WC	XX	VO	XX	3OP	UO	Ø	OUD	A	100	E	Inadvertent Open (wet label also was contributing cause.)
50	053	013504			100775	102175	PC	XX	VH	TB	3FP	CO	2D	AD	A	100	E	Wrong Procedure Followed (out-of-date procedure for valve lineup.)
51	054	013890			112775	121175	MA	XX	TX	XX	2RL	CO	Z	2RL	A	099	E	Improper Release (misread of the amount on the permit.)
52	055	014805			011076	012776	RC	XX	OO	XX	5MD	CO	225M	ROL	A	090	E	Misunderstanding (use of graph showing limits of positive power imbalance.)

Table 13.9. (Continued)

	S.N.	R.N.	Plant: Name	Plant: Dock	Event Date	Report Date	System: Involved	System: Affected	Component: Involved	Component: Affected	Failure Mode	Personnel	Duration	Discovery: Cue	Discovery: Method	Plant: Power	Plant: Mode	Remarks:
53	057	000773	0E2	270	012274	022174	SB	XX	CB	PM	3FP	CO	231M	ROL	A	Ø	G	Wrong Procedure Followed (out-of-date procedure for minimum operable trains.)
54	058	010405			062074	062874	RB	XX	00	XX	1FP	CO	750M	ROL	A	100	F	Did Not Follow Procedure (power level vis reactivity xenon equilibrium.)
55	059	010389			053174	070174	MC	XX	RM	XX	1RN	EO	18H	ROL	A	050	C	Did Not Return to Service (after calibration).
56	060	010974			092874	101174	RB	RC	00	XX	1FP	CO	Z	ROL	A	080	B	Did Not Follow Procedure (power level vis reactivity Xenon equilibrium.)
57	061	010899			092874	101174	SF	XX	VO	XX	1VF	SS +M	5M	RSL	A	Z	B	Did Not Verify (operability of redundant component before removing the operable one for inspection.)
58	062	011069			111474	121374	SB	XX	VM	PM	1CL	EO	27D	OWI	B	100	E	Left Open (after valve lineup; Positions and labels may be contributing causes.)
59	063	011208			122374	011074	CG	XX	VM	FS	1CL	EO	Z	OUD	A	100	E	Left Open.
60	064	012293			011575	013075	RB	XX	AL	CR	5NR	CO	Z	OUD	A	099	E	No Response (overlap between two rod groups below limits.)
61	065	012294			012275	012175	SF	XX	CB	VO	4CM	UO	Z	RI	A	Z	C	Did Not Tag (procedure unfamiliarity) Communication (between utility and control operators).
62	066	012295			011375	022175	SH	XX	CB	PM	4CM	UO	1H	ROL	A	Z	C	Did Not Place in Service (procedure unfamiliarity). Communication (between utility and control operators).
63	067	012295			011375	022175	SH	XX	00	XX	1RV	UO	1H	ROL	A✓	Z	C	Did Not Review (white tag log).
64	068	012456			032275	040875	RB	XX	00	XX	5MT	CO	Z	ROL	A	080	F	Misinterpretation (power level vis reactivity xenon equilibrium calculations.)
65	069	012632			032675	043075	CB	XX	AL	TX	5MF	CO	20M	OUD	A	Z	F	Misidentification (proximity of the alarm panel.)
66	071	013180			080875	082275	SB	CB	00	XX	5MD	CO	Z	ROL	A	005	C	Misunderstanding (of the purpose and usage of the "out of normal" checklist.)

Table 13.9. (Continued)

	S.N.	R.N.	Plant Name	Plant Dock	Event Date	Report Date	System Involved	System Affected	Component Involved	Component Affected	Failure Mode	Personnel	Duration	Discovery Cue	Discovery Method	Plant Power	Plant Mode	Remarks:
Cont. 67	072	013080			080875	082275	SB	CB	00	00	1CH	CO	Z	ROL	A	005	C	Did Not Check (Trainee's performance).
68	073	013893			111375	120975	CJ	XX	AL	TX	5MF	CO	30M	OUD	A	100	E	Misidentification (low level alarm for high pressure alarm.)
69	074	016739			121576	122076	RB	XX	CR	XX	2WD	CO	Ø	OUD	C	Ø	B	Improper Withdrawal.
70	075	016938			010877	022277	CH	XX	VX	PM	1VF	CO	10D	OUD	A	030	B	Did Not Verify (valve lineup).
71	076	017435			041277	041377	RB	ZZ	ZZ	XX	1FP	CO	31M	ROL	A	025	E	Did Not Follow Procedure (power level > 10% when the the plant in 3 loop status.)
72	077	017700			050677	051077	SF	XX	PM	XX	1PS	CO	130M	ROL	A	Ø	D	Did Not Place in Service (when unit entered mode 3.)
73	079	015504	SL1	335	070576	080576	FC	XX	VX	TX	1CL	CO	Z	OUD	A	078	E	Left Open.
74	080	015512			072376	082376	CB	CF	PM	VX	3ST	CO	Ø	OUD	A	Ø	D	Inadvertent Start.
75	081	016887			112876	122876	ED	CB	BS	PM	1VF	CO	Z	OUD	A	Ø	B	Did Not Verify (proper initial conditions at the beginning of plant evolutions.)
76	082	017441			030177	033077	EE	XX	RY	DG	1RT	EO	Z	OUD	B	081	B	Did Not Reset.
77	084	001141	SU1	280	040373	041873	PC	SF	VO	ZZ	2CL	EO	Z	OUD	A	Ø	G	Improper closure (overtorqued).
78	085	000532			111573	112373	PC	XX	TX	XX	1MR	CO	Z	AD	A	095	E	Did Not Monitor (high pressure).
79	086	010013			041574	050374	EE	XX	PB	CB	1RT	CO	Ø	OUD	B	Z	Z	Did Not Reset (burnt amber light was a confusing factor.)
80	088	012263			011875	022475	SA	XX	VM	XX	1VF	EO	Z	OUD	A	Ø	C	Did Not Verify (valve lineup; similarity of labels was a contributing cause.)

Table 13.9. (Continued)

	S.N.	R.N.	Plant: Name	Plant: Dock	Event Date	Report Date	System: Involved	System: Affected	Component: Involved	Component: Affected	Failure Mode	Personnel	Duration	Discovery: Cue	Discovery: Method	Plant: Power	Plant: Mode	Remarks:
Cont																		
81	089	012646			041275	041875	BB	XX	SM	RM	1PN	CO	24H	RI	B	100	E	Left in Wrong Position (after training).
82	090	012646			041275	041875	BB	XX	SM	RM	1RP	CO	450M	RSL	B	100	E	Did Not Report (discovery and corrective action of the previous event.)
83	091	012455			031375	032075	WC	XX	TX	XX	1MR	CO	2H	OUD	A	100	E	Did Not Monitor (high level).
84	092	013042			080175	081275	SF	XX	VO	AC	20P	CO	24H	OUD	B	004	C	Improper Open (opened at inadequate RC pressure.)
85	093	013872			112975	120975	WC	XX	TX	XX	1MR	CO	Z	OWI	A	Ø	G	Did Not Monitor (high level.)
86	094	013874			120575	121675	WC	XX	TX	XX	1MR	CO	Z	OUD	A	Ø	G	Did Not Monitor (high level).
87	095	015548			072776	072776	SC	XX	SP	XX	1RN	CO	Z	RSL	Z	Ø	G	Did not return to service (oversight).
88	095	015548			072776	072776	SC	XX	OO	XX	1RV	SS	NA	RSL	Z	Ø	G	Did Not Review (jumper log not reviewed at the proper time.)
89	096	000519	SU2	281	111373	112373	SF	XX	FU	PM	1RN	CO	9D	OUD	A	000	G	Did Not Return to Service (after maintenance).
90	098	010259	TI1	289	061374	062164	CJ	XX	VO	PM	1VF	CO	Z	OUD	A	000	B	Did Not Verify (valve lineup before test, faulty position indicator was a contributing cause.)
91	099	010259			061374	062174	CJ	XX	VO	PM	1VF	CO	Z	OUD	A	000	B	Did Not Verify (valve lineup before test, faulty position indicator was a contributing cause.)
92	100	010321			062574	070574	SF	XX	PB	CB	20R	CO	Ø	OUD	A	000	G	Improper Operation (interval between pressing two pushbuttons was short, design was a contributing factor.)
93	101	012144			021075	022175	RB	XX	CD	XX	5UW	CO	10D	PI	A	100	E	Unawareness (of need of thoroughly investigating rod locations even if it is not procedural step.)
94	102	015694			081575	082275	WE	XX	RC	XX	1MR	CO	30M	OUD	A	100	E	Did Not Monitor (high ΔT.)

Table 13.9. (Continued)

	S.N.	R.N.	Plant: Name	Plant: Dock	Event Date	Report Date	System: Involved	System: Affected	Component: Involved	Component: Affected	Failure Mode	Personnel	Duration	Discovery: Cue	Discovery: Method	Plant: Power	Plant: Mode	Remarks:
95	104	013492			091875	092675	SD	XX	VM	XX	10P	EO	Z	RI	B	100	e	Left Closed (after test).
96	105	013557			102175	103175	RB	XX	CR	XX	5MT	CO	Z	RSL	B	089	E	Misinterpretation (CR program verification proc., Proc. inadequacy was a contributing cause.)
97	106	015698			111375	112075	CF	XX	RC	XX	1MR	CO	20M	OUD	A	Ø	G	Did Not Monitor (high T when entering different mode.)
98	107	013735			111475	112475	RB	XX	CD	XX	1FP	CO	Ø	OUD	A	Ø	G	Did Not Follow Procedure (for proper CD venting.)
99	108	013766			112575	120575	CG	CB	MN	TX	3RD	CO	41M	OUD	A	010	C	Misread (confusion between two different level indicators).
100	109	013792			121075	121975	SD	XX	VP	VM	1PN	EO	16D	OUD	B	100	E	Left in Wrong Position (after backseating to minimize leakage.)
101	110	016264			102176	110476	RB	XX	FU	CR	6PI	P	Z	OUD	A	054	E	Procedure Inadequacy (regarding monitoring overlap when sequence fault signal is present.)
102	111	016663			121276	010577	CF	XX	PM	XX	4CM	CO	Z	RSL	A	100	E	Did Not Test (redundant component) Communication (between operation personnel).
103	113	013977	TR1	344	121975	011976	CH	XX	SX	EG	6PI	P	Z	OUD	A	000	B	Procedure Inadequacy (regarding sequences of operation).
104	114	014145			011676	012776	CH	CC	TP	PM	2RP	CO	Z	RT	A	024	B	Misreport (logging of lifted lead in auto-start circuitry in wrong portion of jumper log.)
105	115	014252			011876	021876	IB	XX	TT	XX	4CM	CO	3D	OUD	A	030	E	Did Not Return to Service (after test). Communication (between I & C and control operators).
106	116	014227			020576	021876	IA	XX	SC	XX	1PN	CO	NA	OUD	B	Ø	G	Left in Wrong Position
107	117	014227			020576	021876	IA	XX	AL	XX	5NR	CO	Z	AD	B	Ø	G	No Response (out of order alarm).
108	117	014227			020576	021876	IA	XX	SC	XX	2RS	CO	Z	RT	B	Ø	G	Improper Removal from Service (for test with the redundant train inoperable.)
109	118	014599			041676	051476	EA	ZZ	BS	ZZ	10B	M	Z	RI	A	Ø	B	Failure to Observe (disconnects not completely closed.)
110	119	015173			050676	062376	PD	XX	DO	XX	5PU	CO	16H	RSL	B	090	B	Procedure Unfamiliarity (iodine analysis not done when power was changed.)

Table 13.9. (Continued)

	S.N.	R.N.	Plant: Name	Plant: Dock	Event Date	Report Date	System: Involved	System: Affected	Component: Involved	Component: Affected	Failure Mode	Personnel	Duration	Discovery: Cue	Discovery: Method	Plant: Power	Plant: Mode	Remarks:
242	247	017255			021877	010477	SF SIS	XX	VM	XX	OP	EO	5H	RI	A	100	E	Inadvertent Open (1 VC8555 was closed instead of 2VC8555, no tags were attached for identification purpose)
243	251	019179			070877	100677	CH	XX	VX	XX	3FP	CO	2D	SI	A	000	G	Wrong Procedure Followed (throttle position for valves had been changed in a newer version of test proc. to prevent waterhammer, but not followed)
244	252	000769	ZI2	304	020774	021674	PC	XX	VM	XX	3CL	EO	Z	OWI	A	000	G	Inadvertent Closure (during previous operations resulted in system overpressure and diaphragm rupture)
245	253	000808			021774	022774	EE	CH	SX	PM	2PN	EO	Z	OUD	B	025	B	Improper Setting (high synchrospeed setting caused the DG to trip)
246	253	000808			021774	022774	EE	CH	DG	PM	1FP	EO	162M	OUD	B	025	B	Procedure Violation (time to correct DG defects exceed the limit allowable to operate without the only operable AFWP)
247	254	010707			071874	071874	SD	XX	VM	XX	10P	CO	98D	RI	A	000	G	Left Closed (after leakage test during the unit outage)
248	255	010705			082274	082874	CC	XX	VM	VR	10P	CO	7D	RI	A	000	G	Left Closed (after maintenance work completion)
249	256	010705			082274	082874	CC	XX	VM	VR	10P	CO	7D	RI	A	000	G	Left Closed (after maintenance work completion)
250	261	012469			040175	041175	PC	XX	TB	XX	5MJ	CO	1D	RSA	B	084	E	Misjudgment (failure to increase boron concentration although sample results showed the adverse trend)
251	263	013453			091875	092675	CB	RC	OO	XX	6PD	P	Z	OUD	A	000	G	Procedure Deficiency (lacking of sufficient warning of the potential of RCS pressure increase)
252	263	013453			091875	092675	BC	RC	ZZ	XX	5SR	CO	Z	OUD	A	000	G	Slow Response (in reducing RCS peak pressure)
253	264	013539			102275	103175	SB	XX	VM	VO	10P	CO	6H	OUD	B	082	E	Did Not Open (the valve has been overlooked on the realignment process
254	265	014523			041176	051176	SO	XX	VX	XX	2AJ	M	Z	AD	A	000	G	Misadjustment (controller for the N_2 pressure control valve was set too high after maintenance, resulted in depressurization of Zone 1)

Table 13.9. (Continued)

	S.N.	R.N.	Plant: Name	Plant: Dock	Event Date	Report Date	System: Involved	System: Affected	Component: Involved	Component: Affected	Failure Mode	Personnel	Duration	Discovery: Cue	Discovery: Method	Plant: Power	Plant: Mode	Remarks:
255	266	016051			091976	092976	EE	CB	BS	PM	3DG	CO	Ø	RI	A	030	C	Inadvertent Deenergization (due to switching error)
256	267	017407			031077	032477	SD	CB	CM	PM	1CL	EO	Z	OUD	A	ØØØ	G	Left Open (resulted in 3 ft. increase in RC level)
257	268	018393			071277	072577	IA	CC	ØØ	XX	5MT	CO	Ø	OUD	A	ØØØ	G	Misinterpretation (of instruction concerning the placement of dummy signals)
258	269	019137			083177	092677	SF ACC	XX	VX	AC	3OP	CO	Z	OUD	A	098	E	Inadvertent Open (during attempting to lower ACC level, it was lowered below T.S. limits)
259	270	012611	EH1	321	012775	050575	CF	XX	ST	VO	2PN	M	Z	OUD	A	ØØØ	B	Improper Setting
260	273	012459			032075	040275	HC	XX	AL	XX	5NR	CO	Z	OUD	A	040	V	No Response (off gas H_2 concentration exceeded limit, CO did not close discharge valve)
261	274	013045			072976	101576	CA	CD	ZZ	XX	3FP	CO	2M	RT	A	084	C	Wrong Procedure Followed (while performing surv. on ADS resulted in low RPV pressure)
262	275	013602			101975	102275	MA	XX	VM	TX	4CM	EO	Z	RI	A	086	E	Left Open (after lineup in previous shift, resulted in discharging wrong tank)
263	276	013700			110475	112775	IF	XX	VM	MN	3CL	EO	1D	RI	B	050	E	Inadvertent Close (during operation, resulted in isolating pH instrument)
264	277	013902			120375	121275	MA	XX	VX	TX	2AL	CO	Z	OUD	A	ØØØ	G	Improper Lineup (resulted in unplanned discharge)
265	278	014106			010276	012876	SF CSIS	XX	OO	XX	1TS	CO	4D	RSL	B	050	E	Did Not Test (CO was unduly apprehensive to avoid unnecessary cycling)
266	279	015566			072376	080276	CD	XX	SP	XX	1TS	CO	Z	RSL	A	083	E	Did Not Test (oversight)
267	280	017335			021977	031977	ID	XX	MN	XX	1TS	CO	2D	RSL	A	001	G	Did Not Test (oversight)
268	282	018146			053077	052677	ID	XX	MN	XX	1TS	CO	690M	RSL	B	ØØØ	H	Did Not Test (oversight)
269	283	018142			051777	060977	MA	XX	VO	XX	1TS	CO	4D	RSL	A	ØØØ	H	Did Not Test (oversight)

Table 13.9. (Continued)

	S.N.	R.N.	Plant Name	Plant Dock	Event Date	Report Date	System Involved	System Affected	Component Involved	Component Affected	Failure Mode	Personnel	Duration	Discovery Cue	Discovery Method	Plant Power	Plant Mode	Remarks:
349	368	014141			020276	030176	SF CSS	XX	CB	VO	1TG	EO	Z	RI	Z	ØØØ	H	Did Not Tag (during reactor vessel head removal for refueling)
350	369	015448			080576	090376	EE	XX	DG	XX	5MD	EO	13D	ROL	A	067	E	Misunderstanding (DG was returned to operable status without retesting)
351	370	019474			103077	110977	CF	CC	VX	PP	2AL	EO	Z	SD	A	ØØØ	G	Improper Lineup (during manual valving operation - water hammer occurred)
352	371	013015	AR1	368	070775	071675	SF ECCIS	XX	VX	PM	4CM	CO	177M	PI	A	093	E	Left Open (after pump alignment for ES standby i.e., with no suction) Communications (between operators)
353	373	015247			071476	072676	RB	XX	00	XX	5MT	CO	Z	ROL	A	083	F	Misinterpretation (of computer calculations of xenon worth)
354	374	018847			080577	082577	EF	XX	DG	XX	1TS	EO	60	RSL	B	091	E	Did Not Test (surv. test on DG not performed on time)
355	375	018901			082677	090877	SE	XX	VX	FS	2AL	CO	Z	DUD	B	100	E	Improper Lineup (while placing H_2 purge system in service resulted in improper flow)
356	377	017483	PV1	334	030177	042177	CF	CB	VX	XX	1CL	CO	Z	DUD	A	ØØØ	G	Left Open (after filling RHRS resulted in high boron concentration in RCS)
357	378	017565			033177	042977	CH	WC	PM	TX	2)R	CO	3H	DUD	A	ØØØ	G	Improper Operation (continuing using AFWP's while make-up water was unavailable for PPDWST)
358	379	017694			042777	052077	IE	XX	DT	XX	2CN	CO	270M	DUD	A	100	E	Improper Connection (Detector #2 of APDMS was connected to thimble C-8 rather than thimble F-9)
359	380	005005	YR1	029	111869	111969	CB	XX	VM	XX	3OP	EO	Z	RSA	A	Z	E	Inadvertent Open (EO accidently opened a valve from LPST)

Table 13.9. (Continued)

	S.N.	R.N.	Plant: Name	Plant: Dock	Event Date	Report Date	System: Involved	System: Affected	Component: Involved	Component: Affected	Failure Mode	Personnel	Duration	Discovery: Cue	Discovery: Method	Plant: Power	Plant: Mode	Remarks:
360	381	016867			010477	020377	PC	XX	PM	XX	5PU	CO	Z	ROL	A	092	E	Procedure Unfamiliarity (one coolant charging pump was out of service for maintenance, one was in fixed speed mode, and one was in variable speed mode)
361	382	015392	BF2	260	061976	070276	RB	XX	VX	CD	1VF	CO	Z	OUD	B	ØØØ	H	Did Not Verify (valve position; one CRD became incapable of being scrammed)
362	384	010930	CC1	317	103174	111174	SF	XX	SS	XX	1VF	CO	4M	SI	A	ØØØ	G	Did Not Verify (CO tripped the ZD group module "according as required by test proc. without verifying that the ZG module had been tripped for maint.)
363	385	012499			040675	041875	MA	XX	VM	TX	1CL	EO	Z	OUD	A	100	B	Left Open
364	385	012499			040675	041875	MA	XX	VM	TX	1VF	EO	Z	OUD	A	100	B	Did Not Verify (valve position before discharge of RCWMT)
365	386	012935			061275	061975	SH	XX	IO	SS	6PI	P	Z	RI	B	080	F	Procedure Inadequacy (blocking of two logic cabinets negated the responses of all 4 pressurizer pressure sensor channels)
366	386	012935			061275	061975	SH	XX	ZZ	XX	5LE	EO	Z	RI	B	080	F	Lack of Experience (no corrective action was taken)
367	387	013079			071675	072575	MB	XX	VM	XX	1CL	CT	21H	AD	A	099	E	Left Partially Open (following sampling; release of radioactive gas from site boundary; two personnel slightly contaminated)
368	388	013056			072175	073175	MA	XX	TX	XX	3RL	EO	35M	OUD	A	100	E	Inadvertent Release (EO misread valve numbers and released wrong RCWMT)
369	389	015595			073075	080775	RB	XX	ZZ	XX	5MJ	CO		OUD	A	092	F	Misjudgement (failure to reduce power enough to compensate for the reduced sea water condenser flow temperature)
370	390	015594			082875	090475	RB	XX	ZZ	XX	5MJ	CO	Z	OUD	A	087	F	Misjudgement (failure to reduce power enough to

Table 13.9. (Continued)

	S.N.	R.N.	Plant: Name	Plant: Dock	Event Date	Report Date	System: Involved	System: Affected	Component: Involved	Component: Affected	Failure Mode	Personnel	Duration	Discovery: Cue	Discovery: Method	Plant: Power	Plant: Mode	Remarks:
423	450	000605			120473	121273	SA	XX	VM	XX	2AL	CO	9H	AD	A	091	E	Improper Lineup (valve lineup was not changed back after maintenance work)
424	451	010364			062074	070374	MA	XX	TX	XX	2CT	CO	Z	OUD	A	100	E	Improper Calculation (the factor used in calculating the discharge of liquid did effluents from the "A" FDST was increased to 10 without authorization, the operating order permits a maximum factor of 3 without authorization)
425	452	012217			012575	020375	RB	XX	CR	XX	2WD	CO	90M	OUD	Z	ØØØ	H	Improper Withdrawal (of two adjacent control blades during rod drive overhaul)
426	453	012752			052675	060575	SF	XX	VM	XX	1CL	EO	Z	OUD	B	029	E	Left Open (two LPCI header vent valves had been left open)
427	454	012752			052675	060575	LPCI SF	XX	VM	XX	5LE	EO	Z	OUD	B	029	E	Lack of Experience (EO failed to find valve locations)
428	455	012752			052675	060575	SF	XX	VM	XX	3OP	EO	Z	OUD	B	029	E	Inadvertent Open (while venting LPCI header)
429	456	012845			061575	062565	SO	XX	SC	VO	2PN	EO	Z	RI	B	ØØØ	G	Mispositioning (during test, high flow isolation ΔP switch was placed in "AUTO" instead of "CLOSED", this allowed excessive cycling of the valve, its stem was bent)
430	457	013459			092975	100975	SE	XX	VM	XX	1CL	EO	Z	RT	A	037	E	Left Partially Open (resulted in drywell overpressurization and sodium)
431	458	013508			100775	101775	SE	XX	AL	XX	5NR	CO	15M	AD	B	088	E	No Response (failure in heating steam boilers "for liquid N_2"; N_2 entered the line causing cracking)
432	459	013647			103175	110675	SF HPCI	SA	VX	WW	2AL	CO	Z	AD	B	087	E	Misalignment (during HPCI surv.; resulting in storage tank was being discharged to torus whose level exceed T.S. limit)
433	460	014076			010976	012676	IF	XX	SX	ZZ	2PN	EO	2D	RI	B	075	E	Mispositioning (resluted in "B" TIP probe being at wrong position in the shield)
434	461	014333			032276	040676	SF	XX	CB	PM	1RN	M	Z	RI	B	ØØØ	H	Did Not Return to Service (after maintenance)
435	461	014333			032276	040676	SF	XX	PM	XX	1VF	CO	Z	RI	B	ØØØ	H	Did Not Verify (operability of the pump)

Table 13.9. (Continued)

	S.N.	R.N.	Plant: Name	Plant: Dock	Event Date	Report Date	System: Involved	System: Affected	Component: Involved	Component: Affected	Failure Mode	Personnel	Duration	Discovery: Cue	Discovery: Method	Plant: Power	Plant: Mode	Remarks:
445	475	010399			053074	062874	RB	XX	CR	XX	1TS	CO	5D	RSU	A	030	E	<u>Did Not Test</u> (one step of CRD position checks was not completed on five occasions)
446	476	010399			053074	062874	RB	XX	CR	XX	1TS	CO	4D	RSU	A	030	E	<u>Did Not Test</u>
447	478	010399			053074	062874	RB	XX	CR	XX	1TS	CO	12D	RSU	A	030	E	<u>Did Not Test</u>
448	479	010399			053074	062874	RB	XX	CR	XX	1TS	CO	10D	RSU	A	030	E	<u>Did Not Test</u>
449	480	010399			053074	062874	RB	XX	CR	XX	1TS	CO	7D	RSU	A	030	E	<u>Did Not Test</u>
450	482	010571			081074	081674	IA	XX	IM	SP	10P	EO	22D	RI	B	000	B	<u>Left Closed</u> (two reactor pressure switch instrument IV's were found closed. One SP provides a high reactor pressure signal to RPS channels A and B)
451	483	010599			082074	090574	SA	XX	00	XX	1VF	CO	75M	OUD	A	000	B	<u>Did Not Verify</u> (CO initiated the steam condensing mode of RHRS without prior assurance that the radwaste system had the capability to process excess water from the SC; level of SC exceeded T.S. limits)
452	484	010913			101074	102974	IE	XX	ID	XX	1TS	EO	Z	RSU	A	000	B	<u>Did Not Test</u> (Rx restarted without performing the subject shift instrument checks)
453	485	012418			032475	040375	SC	XX	OJ	XX	5MJ	CO	19H	OUD	A	012	E	<u>Misjudgement</u> (CO underestimated the time after which O_2 concentration will decrease to the T.S. limit with Rx in "RUN" mode)
454	486	012520			041975	042375	SA	XX	RC	SU	2RD	CO	Z	OUD	A	044	F	<u>Misread</u> (the on the level recorders; water volume in SC exceeded T.S. limits)
455	487	013106			072275	073175	SA	XX	VX	SU	2AL	CO	28M	OUD	B	059	E	<u>Misalignment</u> (during surv. test' direct flow path from CSS to SC resulted; SC's level exceeded T.S. limit)
456	489	013230			080475	082675	MB	XX	OC	XX	1TS	CO	34D	RSU	B	080	E	<u>Did Not Test</u> (surv. test for SBGTS and SBFUO were not performed; personnel oversight)
457	490	015633			111975	112675	HC	XX	MN	XX	1RC	CO	7H	ROU	A	080	F	<u>Did Not Record</u> (the discharge canal water system tempera- tures "must be logged hourly when the process computer out of service)

Table 13.9. (Continued)

	S.N.	R.N.	Plant: Name	Plant: Dock	Event Date	Report Date	System: Involved	System: Affected	Component: Involved	Component: Affected	Failure Mode	Personnel	Duration	Discovery: Cue	Discovery: Method	Plant: Power	Plant: Mode	Remarks:
467	499	012775			060575	061275	WC	XX	DZ	XX	2PS	CO	9	OUD	A	042	E	Improper Placement Into Service (the "C" condensate demineralizer was put into service before completing the final rinse of the demineralizer; reactor conductivity exceeded T.S. limits)
468	500	012776			060775	061275	CA	XX	00	XX	5IA	CO	Z	OUD	A	010	E	Inattention (temperature between the upper and lower regions of the core exceeded T.S. limits)
469	502	013136			081075	081875	RC	XX	00	XX	4CM	CO	Z	ROL	D	088	B	Communication (poor communication between the operations group and the reactor analyst group resulted in MAPLHGR exceeding the T.S. limit)
470	503	015060			050476	070176	CF	XX	CB	XX	2RS	CO	Z	RSL	A	090	E	Improper Removal From Service (RHR pump "C" breaker was removed from service for maintenance without performing the associated surv.)
471	504	015065			062976	070176	SA	XX	VM	RM	10P	EO	Z	OUD	B	093	E	Left Closed (2 drywell RM suction valves found closed; O_2 concentration in the drywell increased)
472	505	017378			011677	012577	MC	XX	RM	XX	5IA	EO	Z	RI	A	088	E	Inattention (failure to observe that monitoring system was not operating following UPS transfer)
473	506	016977			011477	021177	MC	XX	RM	XX	1TS	EO	1D	RSL	B	088	E	Did Not Test (off-gas process RM functional test not completed in ± 25% of specified interval)
474	507	017370			022877	040177	CB	XX	PM	XX	2OR	CO	Z	ROL	A	061	E	Improper Operation (PM "B" started while PM "A" at speed higher than required by T.S.)
475	508	017337			030377	040177	SO	XX	VP	VO	2OR	EO	Z	OUD	B	060	E	Improper Operation (outboard floor drain IV operator found overridden in the open direction; the valve failed to close on an isolation signal)
476	509	017579			041977	050377	MC	XX	PM	XX	1ST	CO	36H	RI	C	065	E	Did Not Start (failure to restart the plant stack monitoring sample pump after it had been tripped on UPS transfer)
477	510	017726			040277	051977	MC	XX	RM	XX	4CM	CO	14D	RDP	A	087	E	Communication (CO failed to announce an area RM high alarm on the speaker system; one technician received greater than necessary radiation exposure)

Table 13.9. (Continued)

	S.N.	R.N.	Plant Name	Plant Dock	Event Date	Report Date	System Involved	System Affected	Component Involved	Component Affected	Failure Mode	Personnel	Duration	Discovery Cue	Discovery Method	Plant Power	Plant Mode	Remarks:
488	522	019570			111177	112377	MB	XX	TX	XX	2RL	CO	3H	RI	A	ØØØ	H	<u>Improper Release</u> (MGDT-8 released with both building exhaust units inoperable)
489	523	002329	RG1	244	061072	020973	MB	XX	VM	TX	1CL	M	Z	AD	A	Z	Z	<u>Did Not Close</u> (resulted in GDT leakage to pump tank)
490	524	012938			061175	062575	SF SIS	XX	VM	PM	1OP	EO	300	RI	B	090	E	<u>Left Closed</u> (during SI, pump monthly surv. testing, two pump discharge MOV's were left closed)
491	525	012907			061775	063075	CB	XX	OO	XX	1FP	CT	Z	RSA	A	080	E	<u>Did Not Follow Procedure</u> (failure to increase the frequency of RC sample test for gross radioactivity concentration; gross radioactivity concentration exceeded T.S. limit)
492	526	013169			081575	082275	FC	XX	VO	XX	2OP	CO	3M	AD	A	100	E	<u>Improper Open</u> (CO closed MOV-851B, erroneously reopened it before the next step to stroke MOV-850B;flow path from RWST to containment pump occurred)
493	527	000176	HN1	213	062173	070373	CG	XX	VM	XX	2CL	CO	Z	OUD	Z	Z	Z	<u>Improper Closure</u> (The valve in the purfication line was overtorqued between the low exchange outlet and RC filter inlet; unplanned release of rad. materials occurred)
494	528	013767			111875	112575	SB	XX	FS	XX	1PS	EA	45M	AD	A	100	E	<u>Did Not Place In Service</u> (CO was told to place filter B in service and isolate filter A, he isolated filter A only this interrupted SW flow to all 4 containment recirculation fan coolers)
495	529	015097			061776	062476	EC	CF	BS	PM	1FP	CO	Z	OUD	Z	Z	Z	<u>Did Not Follow Procedure</u> (bus 6 was loaded with all its normal loads; power lost to RHR pump; auxiliary buses must not be loaded fully)

14. APPENDIX B: DERIVED HUMAN ERROR PROBABILITIES AND RELATED PERFORMANCE SHAPING FACTORS

This appendix presents the estimated human error probabilities (HEPs) and uncertainty bounds related to the operation of valves. The data given in this appendix were taken from Swain and Gultmann's handbook (11). The following two types of valves were considered:

(1) a locally operated valve that is opened or closed by manipulating a handle such as a wheel, and

(2) a motor-operated valve that is remotely controlled by a switch in the control room.

The first type can be designated as a manual valve and the second type as an MOV. It is assumed that the changing of valves from their normal operating position and their subsequent restoration is normally performed by operator personnel. Exceptions are operations performed by maintenance personnel within some area valved off by operating personnel. The meaning of the uncertainty bounds x(y to z) is the best estimate of the HEP is x and it is unlikely that an HEP would be lower than y or higher than z.

Manual operation of controls includes the operation of all kinds of switches, connectors, and valves. Table 14.1 applies to control other than valves and lists errors of commission only.

Table 14.1. Probabilities of errors of commission in operating manual control

Task	HEP
Select wrong control in a group of identical controls identified by tables only	3×10^{-3} $(10^{-3} - 10^{-2})$
Select wrong control from a functionally grouped set of controls	$10^{-3}(5 \times 10^{-4} - 10^{-2})$
Select wrong control from a panel with clearly drawn mimic lines	$5 \times 10^{-4}(10^{-4} - 10^{-3})$
Turn control in wrong direction (no violation of populational stereotypes)	$5 \times 10^{-4}(10^{-4} - 10^{-3})$
Turn control in wrong direction (violates a strong populational stereotype)	$5 \times 10^{-2}(5 \times 10^{-3} - 10^{-1})$
Turn control in wrong direction under high stress (design violates a strong populational stereotype)	$5 \times 10^{-1}(10^{-1} - 9 \times 10^{-1})$
Set a multiposition selector switch to an incorrect setting	$10^{-3}(10^{-4} - 10^{-1})$
Improperly mate a connector	$10^{-2}(10^{-3} - 5 \times 10^{-2})$

Table 14.2. Probabilities of errors of omission by operators in changing or restoring valves[a]

Task - Failure to	HEP
Initiate task of changing or restoring valves	0.001(0.0005 - 0.005)
Change or restore a valve, given task begun	
Written procedures used	Use table B.6
Written procedures not used One valve	0.001(0.0005 - 0.005)
More than one valve	Use table B.7
Tag a valve, circuit breaker, or switch for MOV after changing it	0.001(0.0005 - 0.005)
With level 3 tagging, multiply all relevant HEPs which assume level 2 tagging by 10 Owith maximum HEP of .5)	
With first-level tagging, complete dependence is assumed between all steps in a task	0.001(0.0005 - 0.005)
Lock a valve after restoration (if required)	0.005(0.002 - 0.02)
With first-level locking, failure to lock a valve after restoration (if required)	0.001(0.0005 - 0.005)

[a]Second level tagging and locking are assumed unless otherwise stated.

Table 14.3. Probabilities of errors of commission by operator changing or restoring manual or motor-operated valves[a]

Task	HEP
Operator selects wrong valve where the valve is one of the two or more adjacent, similar-appearing valves, and at least one other valve is in the same state as the desired valve; or the valves are MOVs of a type such that valve status cannot be determined at the valve itself	$5\text{x}10^{-3}(2\text{x}10^{-3} - 2\text{x}10^{-2})$
Reversal error: Operator "changes" a valve that had already been changed and tagged by someone else; this error would restore the valve to its normal position	$10^{-4}(5\text{x}10^{-5} - 10^{-3})$
Reversal error if the valve had been changed and not tagged	$10^{-1}(10^{-2} - 5\text{x}10^{-1})$
Operator manipulates wrong MOV switch or circuit breaker in a group of similar-appearing items	$3\text{x}10^{-3}(10^{-3} - 10^{-2})$
Failure to complete a change of a state of an MOV of the type that requires the operator to hold the switch until the change is completed	$3\text{x}10^{-3}(10^{-3} - 10^{-2})$
Failure to note that there is more than one tag on a valve (or MOV circuit breaker or switch) that he has decided to restore	$10^{-4}(5\text{x}10^{-5} - 5\text{x}10^{-4})$
Given that a manual valve sticks, operator erroneously concludes that the valve is fully open (or closed):	
Rising-stem valve	
If the valve sticks at about 3/4 or more of its full travel (no position indicators present)	$5\text{x}10^{-3}(2\text{x}10^{-3} - 2\text{x}10^{-2})$

[a]HEPS below apply to both first and second level tagging.

Table 14.3. (Continued)

Task	HEP
If there is an indicator showing the full extent of travel.	
All other valves	
If there is a position indicator on the valve	$10^{-3}(5x10^{-4} - 10^{-2})$
If there is a position indicator located elsewhere (and extra effort is required to look at it)	$2x10^{-3}(10^{-3} - 10^{-2})$
If there is no position indicator	$10^{-2}(3x10^{-3} - 10^{-1})$

Table 14.4. Probabilities of errors by second operator checking valve changing or restoration tasks by a first operator

Task	HEP
Failure to initiate checking task	$10^{-3}(5x10^{-4} - 5x10^{-3})$
Errors by checker given oral instructions	Use table B.2
For other checking errors	Use tables B.2 & B.3

Table 14.5. Probabilities of error in preparation of written procedures

Task	HEP
Omitting an item	$3x10^{-3}(15x10^{-4} - 15x10^{-3})$
Writing an item incorrectly	$3x10^{-3}(15x10^{-4} - 15x10^{-3})$

Table 14.6. Probabilities of error of omission in use of written procedures in nonpassive tasks

Task	HEP
Procedures with checkoff provision	
Short list, 10 items	$10^{-3}(10^{-4} - 5x10^{-3})$
Long list, 10 items	$3x10^{-3}(8x10^{-4} - 10^{-2})$
Procedures with no checkoff provisions	
Short list, 10 items	$3x10^{-3}(8x10^{-4} - 10^{-2})$
Long list, 10 items	$10^{-2}(10^{-3} - 5x10^{-2})$
Checkoff provision improperly used	$5x10^{-5}(10^{-1} - 9x10^{-1})$
Procedures available but not used	
Maintenance tasks	$5x10^{-1}(10^{-1} - 9x10^{-1})$
Valve change or restoration tasks	$10^{-2}(5x10^{-3} - 5x10^{-2})$

Table 14.7. Probabilities of errors in recalling special instruction items given orally

Task	HEP
Failure to recall any given item, given that these items:	
1.	$10^{-3}(5x10^{-4} - 5x10^{-3})$
2.	$3x10^{-3}(15x10^{-4} - 15x10^{-3})$
3.	$10^{-2}(5x10^{-4} - 5x10^{-3})$
4.	$3x10^{-2}(15x10^{-4} - 15x10^{-3})$
5.	$10^{-1}(5x10^{-3} - 5x10^{-2})$
Unrecovered failure to recall first item if supervisor checks to see that the task was done	Negligible
If item is written down by recipient:	
Failure to recall any item (exclusive of errors in writing)	$10^{-3}(5x10^{-4} - 5x10^{-3})$

15. APPENDIX C: DESCRIPTION OF THE PREP CODES AND ITS INPUT DATA

The PREP program is designed for use as a preprocessor for the KITT programs. The PREP programs find the minimal cut sets and/or the minimal path sets from the system's fault tree and output them in format compatible for use with KITT.

The programs are written in Fortran IV for the IBM 360/75 computer and are capable of finding the minimal cut and path sets for fault trees with up to 2000 components and up to 2000 logical gates. The PREP minimal cut sets may be obtained by either deterministic testing or Monte Carlo simulation. The system's minimal path sets are found by Monte Carlo simulation. The code is composed of two sections: TREBIL which reads the input and generates the logical equivalent of the fault tree, and MINSET which obtains the minimal cut or path sets of the fault tree.

The TREBIL program is designed to accept a description of the system fault tree in a format which is natural for the engineer, and to generate a logical equivalent of that fault tree.

One card is read in for each logical gate in the fault tree. The card contains the name of the gate, the type of the gate ("AND" or "OR"), the number and names of the other gates which are attached to it, and the number and names of components which are attached to it. Since TREBIL is designed to accept only "AND" gates and "OR" gates as input, other types of gates must be described in terms of these simple gate types.

Fig. 8.4 shows the logical subroutine TREE generated by TREBLE. Each component is internally indexed by TREBIL and is treated as an element in a FORTRAN logical array (called "X"). Similarly, each gate is indexed and treated as an element in another FORTRAN logical array (called "A").

The MINSET program determines the minimal cut or path sets of the fault tree. The MINSET program allows minimal cut sets to be found by either deterministic testing or by Monte Carlo simulation. Minimal path sets must be found by Monte Carlo simulation.

In deterministic testing (COMBO), each component is first failed individually to obtain the one component minimal cut sets. Next, every possible combination of two components are failed to obtain the two component minimal cut sets. The algorithm proceeds in this manner until minimal cut sets are obtained having n components where n is specified by the user.

Deterministic testing is the most reliable method for obtaining minimal cut sets since it is theoretically possible to test all possible combinations of components.

In order to use COMBO, the starting (MIN) and ending

(MAX) values for the number of components in the minimal cut sets must be specified. If the minimum number specified is 0 (or left blank), then Monte Carlo simulation is used. The maximum number of components allowed by the program is 10 (MAX $\leq$ 10).

In the Monte Carlo simulation (FATE), failures of the components are chosen according to their failure distributions and TREE tested for a system failure. If a failure has occurred, then the set of components which are failed is stored to obtain the minimal cut set. Once the minimal cut set has been found, it is checked against all previously found minimal cut sets to eliminate duplicates. This procedure is called a Monte Carlo trial. An input switch (INDEXI) is provided which causes the program to search for a minimal path set on any trial which does not result in system failure.

The probability of a failure before time t for a component is computed by the exponential distribution. If this probability of a failure before time T is p(t), then

$$p(T) = 1 - \exp(-\lambda T)$$

where

λ = the failure intensity (per hour) for the particular component, and

T = time in hours.

15.1. Input Data Description

The input to TREBIL consists of the three input groups:

(1) Control information;

(2) The fault tree description; and

(3) The failure and repair data for the components.

The total input deck has the following format:

1. TITLE CARD
2. {COMMENTS CARDS}
3. * 6 DATA (b = blank column)
4. {CONTROL PARAMETERS}
5. END
6. {COMMENTS CARDS}
7. * b TREE
8. {FAULT TREE DESCRIPTION}
9. END
10. {COMMENTS CARDS}
11. * b RATES
12. {FAILURE AND REPAIR DATA}
13. END

15.1.1. Input group 1

Input group 1 consists of the control parameters and switches that determine the flow through MINSET, and determine the type of output obtained. The variables for input group 1 are input on two cards. Table 15.1 contains a brief description of the contents of input group 1 along with its format.

15.1.2. Input group 2

Information required for input group 2 is the name of each gate in the fault tree, its type, the number of inputs to it, and the names of its inputs. The information is supplied one gate per card. The input format for input group 2 is given in Table 15.2.

15.1.3. Input group 3

Information required for input group 3 is a failure intensity for each component, repair data for each component, and inhibit failure probabilities. Table 15.3. tains a brief description of the contents of input group 3.

Table 15.1. Input group 1 (control information)

FORTRAN variable		Description	Card columns format (5I10)
1	NG	Number of gates in the fault tree	1-10
2	MIN	Minimum size of the minimal cut sets to be found by deterministic testing (COMBO)	11-20
3	MAX	Maximum size of the minimal cut sets to be found by deterministic testing (COMBO)	21-30
4	IDEX1	Switch which determines if minimal cut sets or minimal path sets are obtained from FATE	31-40
5	IDEX2	Switch which determines whether minimal sets are to be printed or punched, or both	41-50
			Card columns format (4I10, 1F20.3)
6	MCS	Minimum size of the minimal cut sets to be stored by Monte Carlo (FATE)	1-10
7	NREJEC	Random number starter	11-20
8	NTR	Number of Monte Carlo trials to run	21-30
9	IREN	Monte Carlo mixing parameters switch	31-40
10	TAA	Monte Carlo mixing parameters	41-50

Table 15.2. Input group 2 (format for each input card)

	Inputs	Card columns
1	Gate name (any 8 alphanumeric characters)	1-8
2	Blank	9
3	Gate type ("AND" or "OR")	10-12
4	Blank	13
5	Number of gate inputs	14-15
6	Number of component inputs	16-17
7	First input name	19-26
8	Blank	27
	etc.	etc.

Table 15.3. Input group 3 (failure and repair data)

FORTRAN variable	Description	Card columns
NAM (I)	Ith component name	1-8
Blank		9-10
LMDA (I)	Ith component failure intensity (per 10^6 hour) or inhibit, switch indicator	11-20
TAU (I)	Ith component repair time	21-30
Blank		31
NAM (J)	Jth component name	32-39
Blank		40-41
LMDA (J)	Jth component failure intensity (per 10^6 hour) or inhibit, switch indicator	42-51
TAU (J)	Jth component repair time or inhibit failure probability	

The format for input group 3 is (2[A8,2x,F10.6, F10.3, 1x])

16. APPENDIX D: DESCRIPTION OF THE KITT CODES AND ITS INPUT DATA

The KITT codes consist of two sections: KITT-1 and KITT-2. KITT-1 can handle components which are non-repairable or which have a constant repair time t. The failure intensity (λ) of each component is assumed to be constant with respect to time (i.e., exponential failure distributions are only considered). As in kinetic Tree Theory, the components are assumed independent. Further, all the components are assumed to be in their operating state at $t = 0$. KITT-1 is a single phase component code; each component may have only one failure intensity λ and one repair time t for all operation time.

Besides the λ and t for each component, KITT-1 requires as input either the unique minimal cut sets of the fault tree or the unique minimal path sets of the fault tree.

For each component of the fault tree, KITT-1 obtains the following reliability characteristics:

$q(t)$: the probability that the component is in its failed state at time t;

$w(t)$: the expected number of failures the component will suffer per unit time at time t;

$\int_0^t w(t)dt$: the expected number of failures the component will suffer during the time interval from 0 to t;

1-exp($-\lambda t$): the probability that the component will suffer one or more failures during the time intervals from 0 to 5.

KITT-2 is essentially identical to KITT-1 with regard to input and output. The difference between KITT-1 and KITT-2 is the type of component failure and repair distributions which can be handled. KITT-1 can handle components which have constant repair time (t) or which are non-repairable and which have constant failure intensities (λ). Moreover, KITT-1 is a single phase code; each component must have only one value of t and one value of λ for all time (or the component must be nonrepairable for all time). KITT-2 can also handle components which have constant repair time, or which are nonrepairable, and which have constant failure intensities. However, KITT-2 is a multiphase code. The component during different time intervals, called "phase", may have different reliability properties.

The input data for KITT-1 and KITT-2 are given in Tables 16.1 and 16.2, respectively.

Table 16.1. Input for KITT-1

Input Group	Number of Cards	Format	Input Data	Description
1	1	10A8	Title Card	Problem description (any alpha-numeric characters in the 80 columns of the cards)
2	1	I10	NPROB (NPROB7$\geq$1)	Number of parameter runs
3	1	I10	NCOMP (1$\leq$NCOMP$\leq$400)	Total number of unique component plus unique inhibit conditions
4	Varies	8 F10.0	x LMDACI; I = 1, NCOMP	Failure intensity λ (per hour) for the component of index I A nonpositive λ, λ; denoted that component t is an inhibit condition
5	Varies	8 F10.0	TAU (I); I=1, NCOMP	Constant repair time t (hours) for the component of index I. A non-positive repair time (t$\leq$0) denotes a nonrepairable component. For un-inhibit condition ($\lambda\leq$0), T, is the occurrence probability
6	1	I10	ISTOP	Bracket flag. If ISTOP=2, system reliability characteristics are obtained by means of bracketing procedure. If ISTOP=1, bracketing procedure is not used

Table 16.1. (Continued)

Input Group	Number of Cards	Format	Input Data	Description
7	1	2I10,F10.0	NTPT,NOUT, DELTA $2 \leq \mathrm{NTPT} \leq 50$ $\mathrm{NOUT} \geq 1$	NTPT total number of time points at which reliability characteristics are obtained, NOUT print out multiple and DELTA spacing between the time points. If DELTA 0.0, the time points are read in (Input Group 8)
8	Varies	8F10.0	TOT(t); t=1 NTPT	Time points at which the components, set, and system characteristics are obtained. If DELTA 0.0, this input group is skipped
9	1	2I10	NBMAX, IFAG2 $(1 \leq \mathrm{NBMAX} \leq 400)$	Number of outer brackets to obtain, system failure rate correction flag. If IFAG 2=2, the system failure rate correction term is bracketed. If IFAG2=1 or if ISTOP =1 this group is skipped
10	Varies	8I10	NB2(N);N=1, NBMAX $(1 \leq \mathrm{NB2CN})$ $\leq 100)$	Number of inner brackets to obtain for each outer bracket N. If IFAG= 1, or if ISTOP=1 this group is skipped
11	1	I10	IPATH	A flag. If IPATH=1, minimal cut sets are read in. If IPATH=2 minimal path sets are read in
12	1	I10	NCUT $(1 \leq \mathrm{NCUT} \leq 500)$	Total number of unique minimal cut sets

Table 16.1. (Continued)

Input Group	Number of Cards	Format	Input Data	Description
13	Varies	8I10	IMAX, ICUT (k,I); I=1, IMAX $(1\leq IMAX\leq 19)$	Total number of components plus inhibit conditions in the minimal cut or path set, indices of the components and inhibit conditions in the set For NPROB=1 (Input Group 2), there are no more cards to read in. If NPROB>1, read in input groups 14, 15, 16 and 17
14	1	I10	NLAM	Number of components and inhibit conditions which have different failure intensities λ for the new parameter run. If NLAM=0.0, skip Input Group 15 If NLAM<NCOMP, read in Group 15-B
15A	Varies	8F10.0	xLMDA(I) I=1, NCOMP	New failure intensities λ (per hour) for the parameter run. If NLAM=0.0, or <NCOMP, this group is skipped
15B	Varies	4(I10, F10.0)	IND(K), xLMDA (IND (K); K=1, NLAM)	Index of the component on inhibit condition having a new failure intensity, corresponding new failure intensity (per hour). If NLAM=0.0, or NCOMP this group is skipped.

Table 16.1. (Continued)

Input Group	Number of Cards	Format	Input Data	Description
16	1	I10	NTAN	Number of components and inhibit conditions having different repair times for the new parameter run. If NTAN=0.0, no further data to input. If NTAN=NCOMP, read in group 17A If NTAN<NCOMP, read in Input Group 17B
17A	Varies	8F10.0	TAU(I); I=1, NCOMP	New repair times t (hours) for the parameter run. If NATU=0.0, or <NCOMP this group is skipped
17B	Varies	4(I10, F10.0)	IND(K), TAU (IND [k]); K-1, NTAU)	Index of the component or inhibit condition having a new repair time, corresponding new repair time (hours) If NTAU-0.0 or = NCOMP this group is skipped

Table 16.2. Input for KITT-2

Input Group	Number of Cards	Format	Input Data	Description
1	1	10A8	Title Card	Problem description (any alpha-numeric characters in the 80 columns of the card)
2	1	I10	1 NCOMP$\le$350	Total number of unique components plus unique inhibit conditions
3	1	2I10, F10.0	NTpT, NOUT, DELTA $2<$NTpT 50$\le$NOUT 1	Total number of time points at which reliability characteristics are obtained, print out multiple, and spacing between the time points. If DELTA$\le$0.0, the time points are read (Input Group 4)
4	Varies	8F10.0	TOT (t); t=1, NTpT	Time points at which the components, set, and system characteristics are obtained If DELTA>0, this group is skipped
5	1	I10	ISTOP	Bracket flag. If ISTOP=2, system reliability characteristics are obtained by means of bracketing procedure. If ISTOP=1, bracketing procedure not used

Table 16.2. (Continued)

Input Group	Number of Cards	Format	Input Data	Description
6	1	2I10	NBMAX, IFAG2 $1 \le NBMAX \le 100$	Number of outer brackets to obtain, system failure rate correction flag. If IFAG2=2, the system failure rate correction term is bracketed. If IFAG2=1, this correction is not computed. If ISTOP=1 this group is skipped
7	Varies	8I10	NB2(N); N=1	Number of inner brackets for each outer bracket ($NB2(N) \le 30$). If IFAG2=1, this group is skipped
8	1	2I10	IDEX, NPHASE $NPHASE \le 50$	The component index, the number of phases for the component
9	Varies	8F10.0	Tp(L); L=1, NPHASE	The end-times (hours) for each phase in order of increasing phase number. Phase 1 is always assumed to begin at t=0
10	1	I10	IBPHA	Boundary index ($IBPHA \le 50$). If IBPHA=0, there are no boundary conditions imposed on the phase boundaries. If IBPHA>0, IBPHA is the number of such boundary conditions.
11	Varies	8I10	IBPOS (K), K=1, IBPHA	Phase numbers for which there are imposed failure probabilities at the phase beginning time. If IBPHA<0, this group is skipped

Table 16.2. (Continued)

Input group	Number of cards	Format	Input data	Description
12	Varies	8F10.0	QBPOS (K), K=1, IBPHA	Corresponding imposed failure probability for phase IBPOS(K). If IBPHA ≤ 0, this group is skipped
13	Varies	8F10.0	XLMDA(L), TAU(L); L=1, NPHASE	The component failure intensity λ_L (per hour) and repair time t_L (hours) for phase L
14	1	F10.0	Q00	The initial failed probability at t=0, q(0)
15	1	2I10	IDEX, NPHASE NPHASE≤50	The negative of the inhibit condition index, the numbers of phases for the inhibit condition. If there are no inhibit conditions, this group is skipped
16	Varies	8F10.0	TP(L); L=1, NPHASE	The end times (hours) for each phase
17	Varies	8F10.0	PROB(L); L=1, NPHASE	Occurrence probabilities for each phase
18	1	I10	IPATH	Set flag. If IPATH=1, minimal cut sets are used; if IPATH=2, minimal path sets are used
19	1	I10	NCUT (NCUT< 50)	Number of minimal cut or path sets
20	Varies	8I10	IMAX, ICUT (K,I); I=1, IMAX	Number of components plus inhibit conditions in the set (IMAX≤19), list of components and inhibit indices in the set. For more than 7 indices, continue on the next card with the same format (8I10)

17. APPENDIX E: KITT-1 OUTPUT RESULTS FOR THE CSIS FAULT TREE

Because of the similarities of the KITT-1 output for the three cases (WASH-1400, LERs and NUREG), only a sample from the KITT-1 output results for the first case is given here.

Tables are given here for quick translation of the KITT-1 output. Table 17.1 gives information concerning the component. Table 17.2 gives information concerning the minimal cut set. Table 17.3 gives information concerning the system-upper bound. In addition to that, KITT-1 output results for the CSIS fault tree are given (see pages 303-316).

Table 17.1. Key to component and inhibit information

Program output	Information
T (hours)	t, time (in hours)
Q	q(t), the component failed probability
W	w(t), the component failure rate (per hour)
L	λ, the (input) component failure intensity (per hour)
	$\int_0^t w(t')dt'$, the expected number of failures to time t
FSUM	$1-\exp(-\lambda t)$, the probability of one or more failures to time t

Table 17.2. Key to minimal cut sets information

Program output	Information
T (hours)	t, time (in hours)
Q	$Q'(t)$, the minimal cut set failed probability
W	$W'(t)$, the minimal cut set failure rate (per hour)
L	$\lambda(t)$, the minimal cut set failure intensity (per hour)
WSUM	$\int_0^t W'(t)dt'$, the expected number of failures to time t
FSUM	$1-\exp[-\int_0^t \Lambda'(t')dt']$, the probability of one or more failures to time t

Table 17.3. Key to system information - upper bounds

Program output	Information
T (hours)	t, time (in hours)
Q	$1-\prod_{i=1}^{N_c} [1-Q_i'(t)]$, the upper bound for $Q_0(t)$
W	$\sum_{i=1}^{N_c} W_i'(t)$, the upper bound for $W_0(t)$ (per hour)
L	$\dfrac{\sum_{i=1}^{N_c} W_i(t)}{\prod_{i=1}^{N_c} [1-Q_i'(t)]}$, the upper bound for $\Lambda_0(t)$ (per hour)
WSUM	$\int_0^t \sum_{i=1}^{N_c} W_i'(t')]dt'$, the upper bound for $\int_0^t W_0(t')dt'$
FSUM	$1-\exp\{-\int_0^t \dfrac{\prod_{i=1}^{N_c} W_i'(t')}{\sum_{i=1}^{N_c} [1-Q_i'(t)]}]dt'\}$, the upper bound for $1-\exp[-\int_0^t \Lambda_0(t')dt']$

****
* PROBLEM TITLE FOR THIS ANALYSIS BY KITT-1. SAFTY ANALYSIS PROBLEM FOR CONVERSION CHECKING
****

NO. OF PARAMETER RUNS (NPROB) = 1

NO. OF COMPONENTS AND INHIBIT CONDITIONS (NCOMP) = 21

COMPONENT DATA (LAMBDA AND TAU)
(NON-POSITIVE TAU DENOTES NON-REPAIR)
(NON-POSITIVE LAMBDA DENOTES INHIBIT CONDITION)

COMPONENT INDEX	LAMBDA	TAU
1	2.80000000D-08	3.60000000D 02
2	2.80000000D-08	3.60000000D 02
3	7.50000000D-07	4.00000000D 02
4	1.30000000D-05	3.60000000D 02
5	2.80000000D-08	3.60000000D 02
6	3.05000000D-06	3.60000000D 02
7	3.00000000D-08	3.60000000D 02
8	3.00000000D-05	3.60000000D 02
9	3.00000000D-05	3.60000000D 02
10	3.00000000D-08	5.00000000D-01
11	2.80000000D-06	3.00000000D 02
12	3.00000000D-08	4.40000000D 03
13	3.00000000D-06	3.60000000D 02
14	3.00000000D-10	1.00000000D 01
15	2.80000000D-07	3.60000000D 02
16	3.00000000D-06	3.60000000D 02
17	3.00000000D-07	4.00000000D 02
18	8.00000000D-07	4.00000000D 02
19	1.00000000D-10	2.40000000D 01
20	1.00000000D-10	2.40000000D 01
21	1.00000000D-10	4.40000000D 03

BRACKET FLAG (ISTOP). IF ISTOP=2 SYSTEM INFORMATION IS OBTAINED FROM BRACKETING. IF ISTOP=1 IT IS NOT.
FOR THIS PROBLEM ISTOP = 2

NO. OF TIME POINTS (NTPT) = 20
PRINT OUT MULTIPLE (NOUT) = 1
MESH SIZE (DELTA) = 5.00000000D 01 HOURS

NUMBER OF OUTER BRACKETS (NBMAX) = 10
FAILURE RATE CORRECTION FLAG (IFAG2) = 2

INNER BRACKETS FOR IFAG2=2
OUTER BRACKET NO. (M)   NO. OF INNER BRACKETS (NB2(M))

1	10
2	9
3	8
4	7
5	6
6	5
7	4
8	3
9	2
10	1

SET FLAG (IPATH). IF IPATH=1 MINIMAL CUT SETS ARE USED. IF IPATH=2 MINIMAL PATH SETS ARE USED.
FOR THIS PROBLEM IPATH = 1

NO. OF SETS (NCUT) = 19

SET INFORMATION

SET NO. 1. WITH COMPONENTS - 5

SET NO. 2. WITH COMPONENTS - 6

SET NO. 3. WITH COMPONENTS - 7

SET NO. 4. WITH COMPONENTS - 8

SET NO. 5. WITH COMPONENTS - 9

SET NO. 6. WITH COMPONENTS - 10

SET NO. 7. WITH COMPONENTS - 11

SET NO. 8. WITH COMPONENTS - 12

SET NO. 9. WITH COMPONENTS - 13

SET NO. 10. WITH COMPONENTS - 14

SET NO. 11. WITH COMPONENTS - 15

SET NO. 12. WITH COMPONENTS - 16

SET NO. 13. WITH COMPONENTS - 17

SET NO. 14. WITH COMPONENTS - 18

SET NO. 15. WITH COMPONENTS - 19

SET NO. 16. WITH COMPONENTS - 20

SET NO. 17. WITH COMPONENTS - 21

SET NO. 18. WITH COMPONENTS - 2 1

SET NO. 19. WITH COMPONENTS - 4 3

COMPONENT AND INHIBIT INFORMATION

CHARACTERISTICS FOR COMPONENT NO. = 1

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	2.8000000D-08	2.8000000D-08	0.0	0.0
5.0000000D 01	1.3999965D-06	2.7999961D-08	2.8000000D-08	1.3999990D-06	1.3999990D-06
1.0000000D 02	2.7999929D-06	2.7999922D-08	2.8000000D-08	2.7999961D-06	2.7999961D-06
1.5000000D 02	4.1999894D-06	2.7999882D-08	2.8000000D-08	4.1999912D-06	4.1999912D-06
2.0000000D 02	5.5999831D-06	2.7999843D-08	2.8000000D-08	5.5999843D-06	5.5999843D-06
2.5000000D 02	6.9999725D-06	2.7999804D-08	2.8000000D-08	6.9999755D-06	6.9999755D-06
3.0000000D 02	8.3999619D-06	2.7999765D-08	2.8000000D-08	8.3999647D-06	8.3999647D-06
3.5000000D 02	9.7999513D-06	2.7999726D-08	2.8000000D-08	9.7999520D-06	9.7999520D-06
4.0000000D 02	1.0079941D-05	2.7999718D-08	2.8000000D-08	1.1199938D-05	1.1199937D-05
4.5000000D 02	1.0079930D-05	2.7999718D-08	2.8000000D-08	1.2599924D-05	1.2599921D-05
5.0000000D 02	1.0079920D-05	2.7999718D-08	2.8000000D-08	1.3999910D-05	1.3999902D-05
5.5000000D 02	1.0079910D-05	2.7999718D-08	2.8000000D-08	1.5399896D-05	1.5399881D-05
6.0000000D 02	1.0079907D-05	2.7999718D-08	2.8000000D-08	1.6799882D-05	1.6799859D-05
6.5000000D 02	1.0079903D-05	2.7999718D-08	2.8000000D-08	1.8199868D-05	1.8199834D-05
7.0000000D 02	1.0079900D-05	2.7999718D-08	2.8000000D-08	1.9599853D-05	1.9599808D-05
7.5000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.0999839D-05	2.0999780D-05
8.0000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.2399825D-05	2.2399749D-05
8.5000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.3799811D-05	2.3799717D-05
9.0000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.5199797D-05	2.5199682D-05
9.5000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.6599783D-05	2.6599646D-05

CHARACTERISTICS FOR COMPONENT NO. = 2

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	2.8000000D-08	2.8000000D-08	0.0	0.0
5.0000000D 01	1.3999965D-06	2.7999961D-08	2.8000000D-08	1.3999990D-06	1.3999990D-06
1.0000000D 02	2.7999929D-06	2.7999922D-08	2.8000000D-08	2.7999961D-06	2.7999961D-06
1.5000000D 02	4.1999894D-06	2.7999882D-08	2.8000000D-08	4.1999912D-06	4.1999912D-06
2.0000000D 02	5.5999831D-06	2.7999843D-08	2.8000000D-08	5.5999843D-06	5.5999843D-06
2.5000000D 02	6.9999725D-06	2.7999804D-08	2.8000000D-08	6.9999755D-06	6.9999755D-06
3.0000000D 02	8.3999619D-06	2.7999765D-08	2.8000000D-08	8.3999647D-06	8.3999647D-06
3.5000000D 02	9.7999513D-06	2.7999726D-08	2.8000000D-08	9.7999520D-06	9.7999520D-06
4.0000000D 02	1.0079941D-05	2.7999718D-08	2.8000000D-08	1.1199938D-05	1.1199937D-05
4.5000000D 02	1.0079930D-05	2.7999718D-08	2.8000000D-08	1.2599924D-05	1.2599921D-05
5.0000000D 02	1.0079920D-05	2.7999718D-08	2.8000000D-08	1.3999910D-05	1.3999902D-05
5.5000000D 02	1.0079910D-05	2.7999718D-08	2.8000000D-08	1.5399896D-05	1.5399881D-05
6.0000000D 02	1.0079907D-05	2.7999718D-08	2.8000000D-08	1.6799882D-05	1.6799859D-05
6.5000000D 02	1.0079903D-05	2.7999718D-08	2.8000000D-08	1.8199868D-05	1.8199834D-05
7.0000000D 02	1.0079900D-05	2.7999718D-08	2.8000000D-08	1.9599853D-05	1.9599808D-05
7.5000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.0999839D-05	2.0999780D-05
8.0000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.2399825D-05	2.2399749D-05
8.5000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.3799811D-05	2.3799717D-05
9.0000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.5199797D-05	2.5199682D-05
9.5000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.6599783D-05	2.6599646D-05

CHARACTERISTICS FOR COMPONENT NO. = 3

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	7.5000000D-07	7.5000000D-07	0.0	0.0
5.0000000D 01	3.7497188D-05	7.4997188D-07	7.5000000D-07	3.7499297D-05	3.7499297D-05
1.0000000D 02	7.4994375D-05	7.4994375D-07	7.5000000D-07	7.4997188D-05	7.4997188D-05
1.5000000D 02	1.1249156D-04	7.4991563D-07	7.5000000D-07	1.1249367D-04	1.1249367D-04

7.0000000D 02	1.0079900D-05	2.7999718D-08	2.8000000D-08	1.9599853D-05	1.9599808D-05
7.5000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.0999839D-05	2.0999780D-05
8.0000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.2399825D-05	2.2399749D-05
8.5000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.3799811D-05	2.3799717D-05
9.0000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.5199797D-05	2.5199682D-05
9.5000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.6599783D-05	2.6599646D-05

CHARACTERISTICS FOR COMPONENT NO. = 6

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	3.0500000D-06	3.0500000D-06	0.0	0.0
5.0000000D 01	1.5245815D-04	3.0495356D-06	3.0500000D-06	1.5246838D-04	1.5248837D-04
1.0000000D 02	3.0491629D-04	3.0490700D-06	3.0500000D-06	3.0495350D-04	3.0495349D-04
1.5000000D 02	4.5737444D-04	3.0486050D-06	3.0500000D-06	4.5739538D-04	4.5739536D-04
2.0000000D 02	6.0979912D-04	3.0481401D-06	3.0500000D-06	6.0981406D-04	6.0981399D-04
2.5000000D 02	7.6217358D-04	3.0476754D-06	3.0500000D-06	7.6220939D-04	7.6220937D-04
3.0000000D 02	9.1454805D-04	3.0472106D-06	3.0500000D-06	9.1458154D-04	9.1458152D-04
3.5000000D 02	1.0669225D-03	3.0467459D-06	3.0500000D-06	1.0669305D-03	1.0669304D-03
4.0000000D 02	1.0972970D-03	3.0466532D-06	3.0500000D-06	1.2192654D-03	1.2192561D-03
4.5000000D 02	1.0971716D-03	3.0466536D-06	3.0500000D-06	1.3715981D-03	1.3715586D-03
5.0000000D 02	1.0970461D-03	3.0466540D-06	3.0500000D-06	1.5239308D-03	1.5238378D-03
5.5000000D 02	1.0969374D-03	3.0466543D-06	3.0500000D-06	1.6762635D-03	1.6760938D-03
6.0000000D 02	1.0968957D-03	3.0466545D-06	3.0500000D-06	1.8285962D-03	1.8283266D-03
6.5000000D 02	1.0968539D-03	3.0466546D-06	3.0500000D-06	1.9809290D-03	1.9805361D-03
7.0000000D 02	1.0968122D-03	3.0466547D-06	3.0500000D-06	2.1332617D-03	2.1327225D-03
7.5000000D 02	1.0967955D-03	3.0466548D-06	3.0500000D-06	2.2855944D-03	2.2848857D-03
8.0000000D 02	1.0967956D-03	3.0466548D-06	3.0500000D-06	2.4379272D-03	2.4370256D-03
8.5000000D 02	1.0967956D-03	3.0466548D-06	3.0500000D-06	2.5902599D-03	2.5891424D-03
9.0000000D 02	1.0967957D-03	3.0466548D-06	3.0500000D-06	2.7425926D-03	2.7412359D-03
9.5000000D 02	1.0967957D-03	3.0466548D-06	3.0500000D-06	2.8949254D-03	2.8933063D-03

CHARACTERISTICS FOR COMPONENT NO. = 7

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	3.0000000D-08	3.0000000D-08	0.0	0.0
5.0000000D 01	1.4999960D-06	2.9999955D-08	3.0000000D-08	1.4999989D-06	1.4999989D-06
1.0000000D 02	2.9999919D-06	2.9999910D-08	3.0000000D-08	2.9999955D-06	2.9999955D-06
1.5000000D 02	4.4999879D-06	2.9999865D-08	3.0000000D-08	4.4999899D-06	4.4999899D-06
2.0000000D 02	5.9999806D-06	2.9999820D-08	3.0000000D-08	5.9999820D-06	5.9999820D-06
2.5000000D 02	7.4999684D-06	2.9999775D-08	3.0000000D-08	7.4999719D-06	7.4999719D-06
3.0000000D 02	8.9999563D-06	2.9999730D-08	3.0000000D-08	8.9999595D-06	8.9999595D-06
3.5000000D 02	1.0499944D-05	2.9999685D-08	3.0000000D-08	1.0499945D-05	1.0499945D-05
4.0000000D 02	1.0799932D-05	2.9999676D-08	3.0000000D-08	1.1999929D-05	1.1999928D-05
4.5000000D 02	1.0799920D-05	2.9999676D-08	3.0000000D-08	1.3499913D-05	1.3499909D-05
5.0000000D 02	1.0799908D-05	2.9999676D-08	3.0000000D-08	1.4999897D-05	1.4999888D-05
5.5000000D 02	1.0799897D-05	2.9999676D-08	3.0000000D-08	1.6499880D-05	1.6499864D-05
6.0000000D 02	1.0799893D-05	2.9999676D-08	3.0000000D-08	1.7999864D-05	1.7999838D-05
6.5000000D 02	1.0799889D-05	2.9999676D-08	3.0000000D-08	1.9499848D-05	1.9499810D-05
7.0000000D 02	1.0799885D-05	2.9999676D-08	3.0000000D-08	2.0999832D-05	2.0999780D-05
7.5000000D 02	1.0799883D-05	2.9999676D-08	3.0000000D-08	2.2499816D-05	2.2499747D-05
8.0000000D 02	1.0799883D-05	2.9999676D-08	3.0000000D-08	2.3999799D-05	2.3999712D-05
8.5000000D 02	1.0799883D-05	2.9999676D-08	3.0000000D-08	2.5499783D-05	2.5499675D-05
9.0000000D 02	1.0799883D-05	2.9999676D-08	3.0000000D-08	2.6999767D-05	2.6999636D-05
9.5000000D 02	1.0799883D-05	2.9999676D-08	3.0000000D-08	2.8499751D-05	2.8499594D-05

CHARACTERISTICS FOR COMPONENT NO. = 8

4.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	1.3499809D-02	1.3409284D-02
5.0000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	1.4999786D-02	1.4886060D-02
5.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	1.6499764D-02	1.6364621D-02
6.0000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	1.7999741D-02	1.7838968D-02
6.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	1.9499719D-02	1.9311105D-02
7.0000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	2.0999696D-02	2.0781035D-02
7.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	2.2499674D-02	2.2248763D-02
8.0000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	2.3989651D-02	2.3714290D-02
8.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	2.5499629D-02	2.5177621D-02
9.0000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	2.6999606D-02	2.6638758D-02
9.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	2.8499584D-02	2.8097706D-02

CHARACTERISTICS FOR COMPONENT NO. = 11

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	2.8000000D-05	2.8000000D-05	0.0	0.0
5.0000000D 01	1.3970641D-03	2.7960882D-05	2.8000000D-05	1.3990221D-03	1.3990205D-03
1.0000000D 02	2.7941282D-03	2.7921764D-05	2.8000000D-05	2.7960882D-03	2.7960837D-03
1.5000000D 02	4.1911923D-03	2.7882647D-05	2.8000000D-05	4.1911965D-03	4.1911923D-03
2.0000000D 02	5.5824011D-03	2.7843693D-05	2.8000000D-05	5.5843570D-03	5.5843492D-03
2.5000000D 02	6.9735098D-03	2.7804739D-05	2.8000000D-05	6.9755676D-03	6.9755571D-03
3.0000000D 02	8.3648186D-03	2.7765785D-05	2.8000000D-05	8.3663090D-03	8.3648186D-03
3.5000000D 02	8.3560642D-03	2.7766030D-05	2.8000000D-05	9.7531263D-03	9.7521365D-03
4.0000000D 02	8.3473098D-03	2.7766275D-05	2.8000000D-05	1.1141434D-02	1.1137514D-02
4.5000000D 02	8.3385554D-03	2.7766520D-05	2.8000000D-05	1.2529754D-02	1.2520952D-02
5.0000000D 02	8.3356607D-03	2.7766601D-05	2.8000000D-05	1.3918082D-02	1.3902456D-02
5.5000000D 02	8.3328061D-03	2.7766681D-05	2.8000000D-05	1.5306414D-02	1.5282026D-02
6.0000000D 02	8.3299314D-03	2.7766762D-05	2.8000000D-05	1.6694760D-02	1.6659667D-02
6.5000000D 02	8.3299598D-03	2.7766761D-05	2.8000000D-05	1.8083088D-02	1.8035380D-02
7.0000000D 02	8.3299881D-03	2.7766760D-05	2.8000000D-05	1.9471426D-02	1.9409169D-02
7.5000000D 02	8.3300164D-03	2.7766760D-05	2.8000000D-05	2.0859764D-02	2.0781035D-02
8.0000000D 02	8.3300202D-03	2.7766759D-05	2.8000000D-05	2.2248102D-02	2.2150983D-02
8.5000000D 02	8.3300241D-03	2.7766759D-05	2.8000000D-05	2.3636440D-02	2.3519014D-02
9.0000000D 02	8.3300280D-03	2.7766759D-05	2.8000000D-05	2.5024778D-02	2.4885130D-02
9.5000000D 02	8.3300279D-03	2.7766759D-05	2.8000000D-05	2.6413116D-02	2.6249336D-02

CHARACTERISTICS FOR COMPONENT NO. = 12

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	3.0000000D-08	3.0000000D-08	0.0	0.0
5.0000000D 01	1.4999505D-06	2.9999955D-08	3.0000000D-08	1.4999989D-06	1.4999989D-06
1.0000000D 02	2.9999010D-06	2.9999910D-08	3.0000000D-08	2.9999955D-06	2.9999955D-06
1.5000000D 02	4.4998515D-06	2.9999865D-08	3.0000000D-08	4.4999899D-06	4.4999899D-06
2.0000000D 02	5.9998020D-06	2.9999820D-08	3.0000000D-08	5.9999820D-06	5.9999820D-06
2.5000000D 02	7.4997525D-06	2.9999775D-08	3.0000000D-08	7.4999719D-06	7.4999719D-06
3.0000000D 02	8.9997030D-06	2.9999730D-08	3.0000000D-08	8.9999595D-06	8.9999595D-06
3.5000000D 02	1.0499654D-05	2.9999685D-08	3.0000000D-08	1.0499945D-05	1.0499945D-05
4.0000000D 02	1.1999604D-05	2.9999640D-08	3.0000000D-08	1.1999928D-05	1.1999928D-05
4.5000000D 02	1.3499555D-05	2.9999595D-08	3.0000000D-08	1.3499909D-05	1.3499909D-05
5.0000000D 02	1.4999505D-05	2.9999550D-08	3.0000000D-08	1.4999888D-05	1.4999888D-05
5.5000000D 02	1.6499456D-05	2.9999505D-08	3.0000000D-08	1.6499864D-05	1.6499864D-05
6.0000000D 02	1.7999406D-05	2.9999460D-08	3.0000000D-08	1.7999838D-05	1.7999838D-05
6.5000000D 02	1.9499357D-05	2.9999415D-08	3.0000000D-08	1.9499810D-05	1.9499810D-05
7.0000000D 02	2.0999307D-05	2.9999370D-08	3.0000000D-08	2.0999780D-05	2.0999780D-05
7.5000000D 02	2.2499258D-05	2.9999325D-08	3.0000000D-08	2.2499747D-05	2.2499747D-05
8.0000000D 02	2.3999208D-05	2.9999280D-08	3.0000000D-08	2.3999712D-05	2.3999712D-05
8.5000000D 02	2.5499159D-05	2.9999235D-08	3.0000000D-08	2.5499675D-05	2.5499675D-05
9.0000000D 02	2.6999109D-05	2.9999190D-08	3.0000000D-08	2.6999636D-05	2.6999636D-05

2.0000000D 02	4.9998650D-05	2.4998750D-07	2.5000000D-07	4.9990750D-05	4.9998750D-05
2.5000000D 02	6.2497806D-05	2.4990438D-07	2.5000000D-07	6.2498047D-05	6.2498047D-05
3.0000000D 02	7.4996963D-05	2.4998125D-07	2.5000000D-07	7.4997188D-05	7.4997188D-05
3.5000000D 02	8.7496119D-05	2.4997813D-07	2.5000000D-07	8.7496172D-05	8.7496172D-05
4.0000000D 02	8.9995275D-05	2.4997780D-07	2.5000000D-07	9.9995063D-05	9.9998000D-05
4.5000000D 02	8.9994431D-05	2.4997750D-07	2.5000000D-07	1.1249394D-04	1.1249367D-04
5.0000000D 02	8.9993588D-05	2.4997750D-07	2.5000000D-07	1.2499281D-04	1.2499219D-04
5.5000000D 02	8.9992557D-05	2.4997780D-07	2.5000000D-07	1.3740169D-04	1.3749085D-04
6.0000000D 02	8.9992575D-05	2.4997750D-07	2.5000000D-07	1.4999056D-04	1.4998875D-04
6.5000000D 02	8.9992294D-05	2.4997750D-07	2.5000000D-07	1.6248944D-04	1.6248680D-04
7.0000000D 02	8.9992013D-05	2.4997750D-07	2.5000000D-07	1.7498831D-04	1.7498469D-04
7.5000000D 02	8.9991901D-05	2.4997750D-07	2.5000000D-07	1.8748719D-04	1.8748242D-04
8.0000000D 02	8.9991901D-05	2.4997750D-07	2.5000000D-07	1.9998606D-04	1.9998000D-04
8.5000000D 02	8.9991901D-05	2.4997750D-07	2.5000000D-07	2.1248494D-04	2.1247742D-04
9.0000000D 02	8.9991901D-05	2.4997750D-07	2.5000000D-07	2.2498381D-04	2.2497469D-04
9.5000000D 02	8.9991901D-05	2.4997750D-07	2.5000000D-07	2.3748269D-04	2.3747180D-04

CHARACTERISTICS FOR COMPONENT NO. = 16

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	3.0000000D-05	3.0000000D-05	0.0	0.0
5.0000000D 01	1.4959573D-03	2.9955121D-05	3.0000000D-05	1.4988780D-03	1.4988756D-03
1.0000000D 02	2.9919146D-03	2.9910243D-05	3.0000000D-05	2.9955121D-03	2.9955045D-03
1.5000000D 02	4.4878718D-03	2.9865364D-05	3.0000000D-05	4.4899023D-03	4.4898902D-03
2.0000000D 02	5.9806066D-03	2.9820582D-05	3.0000000D-05	5.9820509D-03	5.9820359D-03
2.5000000D 02	7.4685074D-03	2.9775945D-05	3.0000000D-05	7.4719641D-03	7.4719452D-03
3.0000000D 02	8.9564083D-03	2.9731308D-05	3.0000000D-05	8.9596454D-03	8.9596212D-03
3.5000000D 02	1.0444309D-02	2.9686671D-05	3.0000000D-05	1.0445995D-02	1.0445067D-02
4.0000000D 02	1.0732262D-02	2.9678032D-05	3.0000000D-05	1.1929212D-02	1.1928287D-02
4.5000000D 02	1.0720228D-02	2.9678393D-05	3.0000000D-05	1.3413123D-02	1.3409284D-02
5.0000000D 02	1.0708194D-02	2.9678754D-05	3.0000000D-05	1.4897052D-02	1.4888060D-02
5.5000000D 02	1.0697780D-02	2.9679067D-05	3.0000000D-05	1.6388997D-02	1.6364621D-02
6.0000000D 02	1.0693846D-02	2.9679185D-05	3.0000000D-05	1.7864954D-02	1.7838968D-02
6.5000000D 02	1.0689911D-02	2.9679303D-05	3.0000000D-05	1.9348916D-02	1.9311105D-02
7.0000000D 02	1.0685977D-02	2.9679421D-05	3.0000000D-05	2.0832884D-02	2.0781035D-02
7.5000000D 02	1.0684433D-02	2.9679467D-05	3.0000000D-05	2.2316856D-02	2.2248763D-02
8.0000000D 02	1.0684483D-02	2.9679466D-05	3.0000000D-05	2.3800829D-02	2.3714290D-02
8.5000000D 02	1.0684533D-02	2.9679464D-05	3.0000000D-05	2.5284803D-02	2.5177621D-02
9.0000000D 02	1.0684583D-02	2.9679463D-05	3.0000000D-05	2.6768776D-02	2.6638758D-02
9.5000000D 02	1.0684589D-02	2.9679462D-05	3.0000000D-05	2.8252749D-02	2.8097706D-02

CHARACTERISTICS FOR COMPONENT NO. = 17

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	3.0000000D-07	3.0000000D-07	0.0	0.0
5.0000000D 01	1.4999550D-05	2.9999550D-07	3.0000000D-07	1.4999888D-05	1.4999888D-05
1.0000000D 02	2.9999100D-05	2.9999100D-07	3.0000000D-07	2.9999550D-05	2.9999550D-05
1.5000000D 02	4.4998650D-05	2.9998650D-07	3.0000000D-07	4.4998988D-05	4.4998988D-05
2.0000000D 02	5.9998200D-05	2.9998200D-07	3.0000000D-07	5.9998200D-05	5.9998200D-05
2.5000000D 02	7.4996850D-05	2.9997750D-07	3.0000000D-07	7.4997188D-05	7.4997188D-05
3.0000000D 02	8.9995500D-05	2.9997300D-07	3.0000000D-07	8.9995950D-05	8.9995950D-05
3.5000000D 02	1.0499418D-04	2.9996850D-07	3.0000000D-07	1.0499449D-04	1.0499449D-04
4.0000000D 02	1.1999280D-04	2.9996400D-07	3.0000000D-07	1.1999280D-04	1.1999280D-04
4.5000000D 02	1.1999145D-04	2.9996400D-07	3.0000000D-07	1.3499100D-04	1.3499089D-04
5.0000000D 02	1.1999010D-04	2.9996400D-07	3.0000000D-07	1.4998920D-04	1.4998875D-04
5.5000000D 02	1.1998875D-04	2.9996400D-07	3.0000000D-07	1.6498740D-04	1.6498639D-04
6.0000000D 02	1.1998740D-04	2.9996400D-07	3.0000000D-07	1.7998560D-04	1.7998380D-04
6.5000000D 02	1.1998695D-04	2.9996400D-07	3.0000000D-07	1.9498380D-04	1.9498099D-04

7.0000000D 02	1.1998680D-04	2.9996400D-07	3.0000000D-07	2.0998200D-04	2.0997798D-04
7.5000000D 02	1.1998605D-04	2.9996400D-07	3.0000000D-07	2.2498020D-04	2.2497469D-04
8.0000000D 02	1.1998560D-04	2.9996400D-07	3.0000000D-07	2.3997840D-04	2.3997120D-04
8.5000000D 02	1.1998560D-04	2.9996400D-07	3.0000000D-07	2.5497660D-04	2.5496749D-04
9.0000000D 02	1.1998560D-04	2.9996400D-07	3.0000000D-07	2.6997480D-04	2.6996358D-04
9.5000000D 02	1.1998560D-04	2.9996400D-07	3.0000000D-07	2.8497300D-04	2.8495939D-04

CHARACTERISTICS FOR COMPONENT NO. = 18

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	8.0000000D-07	8.0000000D-07	0.0	0.0
5.0000000D 01	3.9996800D-05	7.9996800D-07	8.0000000D-07	3.9999200D-05	3.9999200D-05
1.0000000D 02	7.9993600D-05	7.9993601D-07	8.0000000D-07	7.9996800D-05	7.9996800D-05
1.5000000D 02	1.1999040D-04	7.9990401D-07	8.0000000D-07	1.1999280D-04	1.1999280D-04
2.0000000D 02	1.5998720D-04	7.9987201D-07	8.0000000D-07	1.5998720D-04	1.5998720D-04
2.5000000D 02	1.9997760D-04	7.9984002D-07	8.0000000D-07	1.9998000D-04	1.9998000D-04
3.0000000D 02	2.3996800D-04	7.9980803D-07	8.0000000D-07	2.3997120D-04	2.3997120D-04
3.5000000D 02	2.7995840D-04	7.9977603D-07	8.0000000D-07	2.7996080D-04	2.7996080D-04
4.0000000D 02	3.1994881D-04	7.9974404D-07	8.0000000D-07	3.1994881D-04	3.1994881D-04
4.5000000D 02	3.1993921D-04	7.9974405D-07	8.0000000D-07	3.5993601D-04	3.5993521D-04
5.0000000D 02	3.1992961D-04	7.9974406D-07	8.0000000D-07	3.9992321D-04	3.9992001D-04
5.5000000D 02	3.1992001D-04	7.9974406D-07	8.0000000D-07	4.3991041D-04	4.3990321D-04
6.0000000D 02	3.1991042D-04	7.9974407D-07	8.0000000D-07	4.7989762D-04	4.7988482D-04
6.5000000D 02	3.1990722D-04	7.9974407D-07	8.0000000D-07	5.1988482D-04	5.1986482D-04
7.0000000D 02	3.1990402D-04	7.9974408D-07	8.0000000D-07	5.5987202D-04	5.5984323D-04
7.5000000D 02	3.1990082D-04	7.9974408D-07	8.0000000D-07	5.9985923D-04	5.9982004D-04
8.0000000D 02	3.1989763D-04	7.9974408D-07	8.0000000D-07	6.3984643D-04	6.3979524D-04
8.5000000D 02	3.1989763D-04	7.9974408D-07	8.0000000D-07	6.7983364D-04	6.7976885D-04
9.0000000D 02	3.1989763D-04	7.9974408D-07	8.0000000D-07	7.1982084D-04	7.1974085D-04
9.5000000D 02	3.1989763D-04	7.9974408D-07	8.0000000D-07	7.5980805D-04	7.5971127D-04

CHARACTERISTICS FOR COMPONENT NO. = 19

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.0000000D-10	1.0000000D-10	0.0	0.0
5.0000000D 01	2.4000000D-09	1.0000000D-10	1.0000000D-10	5.0000000D-09	5.0000000D-09
1.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	1.0000000D-08	1.0000000D-08
1.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	1.5000000D-08	1.5000000D-08
2.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	2.0000000D-08	2.0000000D-08
2.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	2.5000000D-08	2.5000000D-08
3.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	3.0000000D-08	3.0000000D-08
3.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	3.5000000D-08	3.4999999D-08
4.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	4.0000000D-08	3.9999999D-08
4.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	4.5000000D-08	4.4999999D-08
5.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	5.0000000D-08	4.9999999D-08
5.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	5.5000000D-08	5.4999999D-08
6.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	6.0000000D-08	5.9999998D-08
6.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	6.5000000D-08	6.4999998D-08
7.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	7.0000000D-08	6.9999998D-08
7.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	7.5000000D-08	7.4999997D-08
8.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	8.0000000D-08	7.9999997D-08
8.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	8.5000000D-08	8.4999996D-08
9.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	9.0000000D-08	8.9999996D-08
9.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	9.5000000D-08	9.4999996D-08

CHARACTERISTICS FOR COMPONENT NO. = 20

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.0000000D-10	1.0000000D-10	0.0	0.0
5.0000000D 01	2.4000000D-09	1.0000000D-10	1.0000000D-10	5.0000000D-09	5.0000000D-09
1.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	1.0000000D-08	1.0000000D-08
1.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	1.5000000D-08	1.5000000D-08
2.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	2.0000000D-08	2.0000000D-08
2.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	2.5000000D-08	2.5000000D-08
3.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	3.0000000D-08	3.0000000D-08
3.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	3.5000000D-08	3.4999999D-08
4.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	4.0000000D-08	3.9999999D-08
4.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	4.5000000D-08	4.4999999D-08
5.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	5.0000000D-08	4.9999999D-08
5.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	5.5000000D-08	5.4999999D-08
6.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	6.0000000D-08	5.9999998D-08
6.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	6.5000000D-08	6.4999998D-08
7.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	7.0000000D-08	6.9999998D-08
7.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	7.5000000D-08	7.4999997D-08
8.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	8.0000000D-08	7.9999997D-08
8.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	8.5000000D-08	8.4999996D-08
9.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	9.0000000D-08	8.9999996D-08
9.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	9.5000000D-08	9.4999996D-08

CHARACTERISTICS FOR COMPONENT NO. = 21

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.0000000D-10	1.0000000D-10	0.0	0.0
5.0000000D 01	4.9999994D-09	1.0000000D-10	1.0000000D-10	5.0000000D-09	5.0000000D-09
1.0000000D 02	9.9999989D-09	9.9999999D-11	1.0000000D-10	1.0000000D-08	1.0000000D-08
1.5000000D 02	1.4999998D-08	9.9999999D-11	1.0000000D-10	1.5000000D-08	1.5000000D-08
2.0000000D 02	1.9999998D-08	9.9999998D-11	1.0000000D-10	2.0000000D-08	2.0000000D-08
2.5000000D 02	2.4999997D-08	9.9999998D-11	1.0000000D-10	2.5000000D-08	2.5000000D-08
3.0000000D 02	2.9999997D-08	9.9999997D-11	1.0000000D-10	3.0000000D-08	3.0000000D-08
3.5000000D 02	3.4999996D-08	9.9999997D-11	1.0000000D-10	3.4999999D-08	3.4999999D-08
4.0000000D 02	3.9999996D-08	9.9999996D-11	1.0000000D-10	3.9999999D-08	3.9999999D-08
4.5000000D 02	4.4999995D-08	9.9999996D-11	1.0000000D-10	4.4999999D-08	4.4999999D-08
5.0000000D 02	4.9999994D-08	9.9999995D-11	1.0000000D-10	4.9999999D-08	4.9999999D-08
5.5000000D 02	5.4999994D-08	9.9999995D-11	1.0000000D-10	5.4999998D-08	5.4999999D-08
6.0000000D 02	5.9999993D-08	9.9999994D-11	1.0000000D-10	5.9999998D-08	5.9999998D-08
6.5000000D 02	6.4999993D-08	9.9999994D-11	1.0000000D-10	6.4999998D-08	6.4999998D-08
7.0000000D 02	6.9999992D-08	9.9999993D-11	1.0000000D-10	6.9999998D-08	6.9999998D-08
7.5000000D 02	7.4999992D-08	9.9999993D-11	1.0000000D-10	7.4999997D-08	7.4999997D-08
8.0000000D 02	7.9999991D-08	9.9999992D-11	1.0000000D-10	7.9999997D-08	7.9999997D-08
8.5000000D 02	8.4999991D-08	9.9999992D-11	1.0000000D-10	8.4999996D-08	8.4999996D-08
9.0000000D 02	8.9999990D-08	9.9999991D-11	1.0000000D-10	8.9999996D-08	8.9999996D-08
9.5000000D 02	9.4999990D-08	9.9999991D-11	1.0000000D-10	9.4999995D-08	9.4999996D-08

MINIMAL SET INFORMATION

CHARACTERISTICS FOR SET NO. = 1

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	2.8000000D-08	2.8000000D-08	0.0	0.0
5.0000000D 01	1.3999965D-06	2.7999961D-08	2.8000000D-08	1.3999990D-06	1.3999990D-06
1.0000000D 02	2.7999929D-06	2.7999922D-08	2.8000000D-08	2.7999961D-06	2.7999961D-06
1.5000000D 02	4.1999894D-06	2.7999882D-08	2.8000000D-08	4.1999912D-06	4.1999912D-06
2.0000000D 02	5.5999831D-06	2.7999843D-08	2.8000000D-08	5.5999843D-06	5.5999843D-06
2.5000000D 02	6.9999725D-06	2.7999804D-08	2.8000000D-08	6.9999765D-06	6.9999755D-06
3.0000000D 02	8.3999619D-06	2.7999765D-08	2.8000000D-08	8.3999647D-06	8.3999647D-06
3.5000000D 02	9.7999513D-06	2.7999726D-08	2.8000000D-08	9.7999520D-06	9.7999520D-06
4.0000000D 02	1.0079941D-05	2.7999718D-08	2.8000000D-08	1.1199938D-05	1.1199937D-05
4.5000000D 02	1.0079930D-05	2.7999718D-08	2.8000000D-08	1.2599924D-05	1.2599921D-05
5.0000000D 02	1.0079920D-05	2.7999718D-08	2.8000000D-08	1.3999910D-05	1.3999902D-05
5.5000000D 02	1.0079910D-05	2.7999718D-08	2.8000000D-08	1.5399896D-05	1.5399881D-05
6.0000000D 02	1.0079907D-05	2.7999718D-08	2.8000000D-08	1.6799882D-05	1.6799859D-05
6.5000000D 02	1.0079903D-05	2.7999718D-08	2.8000000D-08	1.8199868D-05	1.8199834D-05
7.0000000D 02	1.0079900D-05	2.7999718D-08	2.8000000D-08	1.9599853D-05	1.9599800D-05
7.5000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.0999839D-05	2.0999780D-05
8.0000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.2399825D-05	2.2399749D-05
8.5000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.3799811D-05	2.3799717D-05
9.0000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.5199797D-05	2.5199682D-05
9.5000000D 02	1.0079898D-05	2.7999718D-08	2.8000000D-08	2.6599783D-05	2.6599646D-05

CHARACTERISTICS FOR SET NO. = 2

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	3.0500000D-06	3.0500000D-06	0.0	0.0
5.0000000D 01	1.5245815D-04	3.0495350D-06	3.0500000D-06	1.5248838D-04	1.5248837D-04
1.0000000D 02	3.0491629D-04	3.0490700D-06	3.0500000D-06	3.0495350D-04	3.0495349D-04
1.5000000D 02	4.5737444D-04	3.0486050D-06	3.0500000D-06	4.5739538D-04	4.5739536D-04
2.0000000D 02	6.0979912D-04	3.0481401D-06	3.0500000D-06	6.0981400D-04	6.0981399D-04
2.5000000D 02	7.6217358D-04	3.0476754D-06	3.0500000D-06	7.6226939D-04	7.6226937D-04
3.0000000D 02	9.1454805D-04	3.0472106D-06	3.0500000D-06	9.1468154D-04	9.1468152D-04
3.5000000D 02	1.0669225D-03	3.0467459D-06	3.0500000D-06	1.0669305D-03	1.0669304D-03
4.0000000D 02	1.0972970D-03	3.0466532D-06	3.0500000D-06	1.2192654D-03	1.2192561D-03
4.5000000D 02	1.0971716D-03	3.0466536D-06	3.0500000D-06	1.3715981D-03	1.3715886D-03
5.0000000D 02	1.0970461D-03	3.0466540D-06	3.0500000D-06	1.5239308D-03	1.5238378D-03
5.5000000D 02	1.0969374D-03	3.0466543D-06	3.0500000D-06	1.6762635D-03	1.6760938D-03
6.0000000D 02	1.0968957D-03	3.0466545D-06	3.0500000D-06	1.8285962D-03	1.8283266D-03
6.5000000D 02	1.0968539D-03	3.0466546D-06	3.0500000D-06	1.9809290D-03	1.9805361D-03
7.0000000D 02	1.0968122D-03	3.0466547D-06	3.0500000D-06	2.1332617D-03	2.1327228D-03
7.5000000D 02	1.0967955D-03	3.0466548D-06	3.0500000D-06	2.2855944D-03	2.2848857D-03
8.0000000D 02	1.0967956D-03	3.0466548D-06	3.0500000D-06	2.4379272D-03	2.4370256D-03
8.5000000D 02	1.0967956D-03	3.0466548D-06	3.0500000D-06	2.5902599D-03	2.5891424D-03
9.0000000D 02	1.0967957D-03	3.0466548D-06	3.0500000D-06	2.7425926D-03	2.7412359D-03
9.5000000D 02	1.0967957D-03	3.0466548D-06	3.0500000D-06	2.8949254D-03	2.8933063D-03

CHARACTERISTICS FOR SET NO. = 3

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	3.0000000D-08	3.0000000D-08	0.0	0.0
5.0000000D 01	1.4999960D-06	2.9999955D-08	3.0000000D-08	1.4999989D-06	1.4999989D-06
1.0000000D 02	2.9999919D-06	2.9999910D-08	3.0000000D-08	2.9999955D-06	2.9999955D-06
1.5000000D 02	4.4999879D-06	2.9999865D-08	3.0000000D-08	4.4999899D-06	4.4999899D-06

7.0000000D 02	1.0685977D-02	2.9679421D-05	3.0000000D-05	2.0832884D-02	2.0781035D-02
7.5000000D 02	1.0684433D-02	2.9679467D-05	3.0000000D-05	2.2316856D-02	2.2248763D-02
8.0000000D 02	1.0684463D-02	2.9679466D-05	3.0000000D-05	2.3800829D-02	2.3714290D-02
8.5000000D 02	1.0684533D-02	2.9679464D-05	3.0000000D-05	2.5284803D-02	2.5177621D-02
9.0000000D 02	1.0684583D-02	2.9679463D-05	3.0000000D-05	2.6768776D-02	2.6638758D-02
9.5000000D 02	1.0684589D-02	2.9679462D-05	3.0000000D-05	2.8252749D-02	2.8097706D-02

CHARACTERISTICS FOR SET NO. = 6

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	3.0000000D-05	3.0000000D-05	0.0	0.0
5.0000000D 01	1.4999775D-05	2.9999550D-05	3.0000000D-05	1.4999888D-03	1.4988756D-03
1.0000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	2.9999663D-03	2.9955045D-03
1.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	4.4999438D-03	4.4898902D-03
2.0000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	5.9999213D-03	5.9820359D-03
2.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	7.4998988D-03	7.4719452D-03
3.0000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	8.9998763D-03	8.9596212D-03
3.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	1.0499854D-02	1.0445067D-02
4.0000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	1.1999831D-02	1.1928287D-02
4.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	1.3499809D-02	1.3409284D-02
5.0000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	1.4999786D-02	1.4885060D-02
5.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	1.6499764D-02	1.6364521D-02
6.0000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	1.7999741D-02	1.7838968D-02
6.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	1.9499719D-02	1.9311105D-02
7.0000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	2.0999696D-02	2.0781035D-02
7.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	2.2499674D-02	2.2248763D-02
8.0000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	2.3999651D-02	2.3714290D-02
8.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	2.5499629D-02	2.5177621D-02
9.0000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	2.6999606D-02	2.6638758D-02
9.5000000D 02	1.4999775D-05	2.9999550D-05	3.0000000D-05	2.8499584D-02	2.8097706D-02

CHARACTERISTICS FOR SET NO. = 7

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	2.8000000D-05	2.8000000D-05	0.0	0.0
5.0000000D 01	1.3970641D-03	2.7960882D-05	2.8000000D-05	1.3990221D-03	1.3990205D-03
1.0000000D 02	2.7941282D-03	2.7921764D-05	2.8000000D-05	2.7960882D-03	2.7960837D-03
1.5000000D 02	4.1911923D-03	2.7882647D-05	2.8000000D-05	4.1911985D-03	4.1911923D-03
2.0000000D 02	5.5824011D-03	2.7843693D-05	2.8000000D-05	5.5843570D-03	5.5843492D-03
2.5000000D 02	6.9736098D-03	2.7804739D-05	2.8000000D-05	6.9755678D-03	6.9755571D-03
3.0000000D 02	8.3648186D-03	2.7765785D-05	2.8000000D-05	8.3648309D-03	8.3648186D-03
3.5000000D 02	8.3560642D-03	2.7766030D-05	2.8000000D-05	9.7531263D-03	9.7521366D-03
4.0000000D 02	8.3473098D-03	2.7766275D-05	2.8000000D-05	1.1141434D-02	1.1137514D-02
4.5000000D 02	8.3385554D-03	2.7766020D-05	2.8000000D-05	1.2529784D-02	1.2520952D-02
5.0000000D 02	8.3368807D-03	2.7766601D-05	2.8000000D-05	1.3918082D-02	1.3902456D-02
5.5000000D 02	8.3328061D-03	2.7766681D-05	2.8000000D-05	1.5306414D-02	1.5282026D-02
6.0000000D 02	8.3299314D-03	2.7766762D-05	2.8000000D-05	1.6694760D-02	1.6659667D-02
6.5000000D 02	8.3299598D-03	2.7766781D-05	2.8000000D-05	1.8083080D-02	1.8035380D-02
7.0000000D 02	8.3299881D-03	2.7766760D-05	2.8000000D-05	1.9471426D-02	1.9409169D-02
7.5000000D 02	8.3300164D-03	2.7766760D-05	2.8000000D-05	2.0859764D-02	2.0781036D-02
8.0000000D 02	8.3300202D-03	2.7766759D-05	2.8000000D-05	2.2248102D-02	2.2150983D-02
8.5000000D 02	8.3300241D-03	2.7766759D-05	2.8000000D-05	2.3636440D-02	2.3519014D-02
9.0000000D 02	8.3300280D-03	2.7766759D-05	2.8000000D-05	2.5024778D-02	2.4885130D-02
9.5000000D 02	8.3300279D-03	2.7766759D-05	2.8000000D-05	2.6413116D-02	2.6249336D-02

CHARACTERISTICS FOR SET NO. = 8

4.5000000D 02	3.0000000D-09	3.0000000D-10	3.0000000D-10	1.3500000D-07	1.3499999D-07
5.0000000D 02	3.0000000D-09	3.0000000D-10	3.0000000D-10	1.5000000D-07	1.4999999D-07
5.5000000D 02	3.0000000D-09	3.0000000D-10	3.0000000D-10	1.6500000D-07	1.6499999D-07
6.0000000D 02	3.0000000D-09	3.0000000D-10	3.0000000D-10	1.8000000D-07	1.7999998D-07
6.5000000D 02	3.0000000D-09	3.0000000D-10	3.0000000D-10	1.9500000D-07	1.9499998D-07
7.0000000D 02	3.0000000D-09	3.0000000D-10	3.0000000D-10	2.1000000D-07	2.0999998D-07
7.5000000D 02	3.0000000D-09	3.0000000D-10	3.0000000D-10	2.2500000D-07	2.2499997D-07
8.0000000D 02	3.0000000D-09	3.0000000D-10	3.0000000D-10	2.4000000D-07	2.3999997D-07
8.5000000D 02	3.0000000D-09	3.0000000D-10	3.0000000D-10	2.5500000D-07	2.5499997D-07
9.0000000D 02	3.0000000D-09	3.0000000D-10	3.0000000D-10	2.7000000D-07	2.6999996D-07
9.5000000D 02	3.0000000D-09	3.0000000D-10	3.0000000D-10	2.8500000D-07	2.8499996D-07

CHARACTERISTICS FOR SET NO. = 11

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	2.5000000D-07	2.5000000D-07	0.0	0.0
5.0000000D 01	1.2499719D-05	2.4999688D-07	2.5000000D-07	1.2499928D-05	1.2499922D-05
1.0000000D 02	2.4999438D-05	2.4999375D-07	2.5000000D-07	2.4999688D-05	2.4999688D-05
1.5000000D 02	3.7499156D-05	2.4999063D-07	2.5000000D-07	3.7499297D-05	3.7499297D-05
2.0000000D 02	4.9998650D-05	2.4998750D-07	2.5000000D-07	4.9998750D-05	4.9998750D-05
2.5000000D 02	6.2497806D-05	2.4998438D-07	2.5000000D-07	6.2498047D-05	6.2498047D-05
3.0000000D 02	7.4996963D-05	2.4998125D-07	2.5000000D-07	7.4997188D-05	7.4997188D-05
3.5000000D 02	8.7496119D-05	2.4997813D-07	2.5000000D-07	8.7496172D-05	8.7496172D-05
4.0000000D 02	8.9995275D-05	2.4997750D-07	2.5000000D-07	9.9995063D-05	9.9995000D-05
4.5000000D 02	8.9994431D-05	2.4997750D-07	2.5000000D-07	1.1249394D-04	1.1249367D-04
5.0000000D 02	8.9993588D-05	2.4997750D-07	2.5000000D-07	1.2499281D-04	1.2499219D-04
5.5000000D 02	8.9992857D-05	2.4997750D-07	2.5000000D-07	1.3749169D-04	1.3749055D-04
6.0000000D 02	8.9992575D-05	2.4997750D-07	2.5000000D-07	1.4999056D-04	1.4998875D-04
6.5000000D 02	8.9992294D-05	2.4997750D-07	2.5000000D-07	1.6248944D-04	1.6248680D-04
7.0000000D 02	8.9992013D-05	2.4997750D-07	2.5000000D-07	1.7498831D-04	1.7498469D-04
7.5000000D 02	8.9991901D-05	2.4997750D-07	2.5000000D-07	1.8748719D-04	1.8748242D-04
8.0000000D 02	8.9991901D-05	2.4997750D-07	2.5000000D-07	1.9998606D-04	1.9998000D-04
8.5000000D 02	8.9991901D-05	2.4997750D-07	2.5000000D-07	2.1248494D-04	2.1247742D-04
9.0000000D 02	8.9991901D-05	2.4997750D-07	2.5000000D-07	2.2498381D-04	2.2497469D-04
9.5000000D 02	8.9991901D-05	2.4997750D-07	2.5000000D-07	2.3748269D-04	2.3747180D-04

CHARACTERISTICS FOR SET NO. = 12

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	3.0000000D-05	3.0000000D-05	0.0	0.0
5.00000000 01	1.4989573D-03	2.9955121D-05	3.0000000D-05	1.4988780D-03	1.4988756D-03
1.0000000D 02	2.9919146D-03	2.9910243D-05	3.0000000D-05	2.9955121D-03	2.9955045D-03
1.5000000D 02	4.4875718D-03	2.9865364D-05	3.0000000D-05	4.4899023D-03	4.4898902D-03
2.0000000D 02	5.9606066D-03	2.9820582D-05	3.0000000D-05	5.9820509D-03	5.9820359D-03
2.5000000D 02	7.4606074D-03	2.9775945D-05	3.0000000D-05	7.4719641D-03	7.4719452D-03
3.0000000D 02	8.9564083D-03	2.9731308D-05	3.0000000D-05	8.9596454D-03	8.9596212D-03
3.5000000D 02	1.0444309D-02	2.9686671D-05	3.0000000D-05	1.0445095D-02	1.0445067D-02
4.0000000D 02	1.0732262D-02	2.9678032D-05	3.0000000D-05	1.1929212D-02	1.1928287D-02
4.5000000D 02	1.0720228D-02	2.9678393D-05	3.0000000D-05	1.3413123D-02	1.3409284D-02
5.0000000D 02	1.0708194D-02	2.9678754D-05	3.0000000D-05	1.4897052D-02	1.4888060D-02
5.5000000D 02	1.0697780D-02	2.9679067D-05	3.0000000D-05	1.6380997D-02	1.6364621D-02
6.0000000D 02	1.0693846D-02	2.9679185D-05	3.0000000D-05	1.7864954D-02	1.7838968D-02
6.5000000D 02	1.0689911D-02	2.9679303D-05	3.0000000D-05	1.9348916D-02	1.9311105D-02
7.0000000D 02	1.0685977D-02	2.9679421D-05	3.0000000D-05	2.0832884D-02	2.0781035D-02
7.5000000D 02	1.0684433D-02	2.9679467D-05	3.0000000D-05	2.2316856D-02	2.2248763D-02
8.0000000D 02	1.0684483D-02	2.9679466D-05	3.0000000D-05	2.3800829D-02	2.3714290D-02
8.5000000D 02	1.0684533D-02	2.9679464D-05	3.0000000D-05	2.5284803D-02	2.5177621D-02
9.0000000D 02	1.0684583D-02	2.9679463D-05	3.0000000D-05	2.6768776D-02	2.6638758D-02

2.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	2.0000000D-08	2.0000000D-08
2.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	2.5000000D-08	2.5000000D-08
3.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	3.0000000D-08	3.0000000D-08
3.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	3.5000000D-08	3.4999999D-08
4.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	4.0000000D-08	3.9999999D-08
4.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	4.5000000D-08	4.4999999D-08
5.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	5.0000000D-08	4.9999999D-08
5.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	5.5000000D-08	5.4999998D-08
6.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	6.0000000D-08	5.9999998D-08
6.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	6.5000000D-08	6.4999998D-08
7.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	7.0000000D-08	6.9999998D-08
7.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	7.5000000D-08	7.4999997D-08
8.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	8.0000000D-08	7.9999997D-08
8.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	8.5000000D-08	8.4999996D-08
9.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	9.0000000D-08	8.9999996D-08
9.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	9.5000000D-08	9.4999995D-08

CHARACTERISTICS FOR SET NO. = 16

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.0000000D-10	1.0000000D-10	0.0	0.0
5.0000000D 01	2.4000000D-09	1.0000000D-10	1.0000000D-10	5.0000000D-09	5.0000000D-09
1.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	1.0000000D-08	9.9999999D-09
1.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	1.5000000D-08	1.5000000D-08
2.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	2.0000000D-08	2.0000000D-08
2.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	2.5000000D-08	2.5000000D-08
3.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	3.0000000D-08	3.0000000D-08
3.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	3.5000000D-08	3.4999999D-08
4.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	4.0000000D-08	3.9999999D-08
4.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	4.5000000D-08	4.4999999D-08
5.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	5.0000000D-08	4.9999999D-08
5.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	5.5000000D-08	5.4999998D-08
6.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	6.0000000D-08	5.9999998D-08
6.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	6.5000000D-08	6.4999998D-08
7.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	7.0000000D-08	6.9999998D-08
7.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	7.5000000D-08	7.4999997D-08
8.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	8.0000000D-08	7.9999997D-08
8.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	8.5000000D-08	8.4999996D-08
9.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	9.0000000D-08	8.9999996D-08
9.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	9.5000000D-08	9.4999995D-08

CHARACTERISTICS FOR SET NO. = 17

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.0000000D-10	1.0000000D-10	0.0	0.0
5.0000000D 01	4.9999994D-09	1.0000000D-10	1.0000000D-10	5.0000000D-09	5.0000000D-09
1.0000000D 02	9.9999989D-09	9.9999999D-11	1.0000000D-10	1.0000000D-08	9.9999999D-09
1.5000000D 02	1.4999998D-08	9.9999999D-11	1.0000000D-10	1.5000000D-08	1.5000000D-08
2.0000000D 02	1.9999998D-08	9.9999998D-11	1.0000000D-10	2.0000000D-08	2.0000000D-08
2.5000000D 02	2.4999997D-08	9.9999998D-11	1.0000000D-10	2.5000000D-08	2.5000000D-08
3.0000000D 02	2.9999997D-08	9.9999997D-11	1.0000000D-10	3.0000000D-08	3.0000000D-08
3.5000000D 02	3.4999996D-08	9.9999997D-11	1.0000000D-10	3.4999999D-08	3.4999999D-08
4.0000000D 02	3.9999996D-08	9.9999996D-11	1.0000000D-10	3.9999999D-08	3.9999999D-08
4.5000000D 02	4.4999995D-08	9.9999996D-11	1.0000000D-10	4.4999999D-08	4.4999999D-08
5.0000000D 02	4.9999994D-08	9.9999995D-11	1.0000000D-10	4.9999999D-08	4.9999999D-08
5.5000000D 02	5.4999994D-08	9.9999995D-11	1.0000000D-10	5.4999998D-08	5.4999998D-08
6.0000000D 02	5.9999993D-08	9.9999994D-11	1.0000000D-10	5.9999998D-08	5.9999998D-08
6.5000000D 02	6.4999993D-08	9.9999994D-11	1.0000000D-10	6.4999998D-08	6.4999998D-08

7.0000000D 02	6.9999992D-08	9.9999993D-11	1.0000000D-10	6.9999998D-08	6.9999998D-08
7.5000000D 02	7.4999992D-08	9.9999993D-11	1.0000000D-10	7.4999997D-08	7.4999997D-08
8.0000000D 02	7.9999991D-08	9.9999992D-11	1.0000000D-10	7.9999997D-08	7.9999997D-08
8.5000000D 02	8.4999991D-08	9.9999992D-11	1.0000000D-10	8.4999996D-08	8.4999996D-08
9.0000000D 02	8.9999990D-08	9.9999991D-11	1.0000000D-10	8.9999996D-08	8.9999996D-08
9.5000000D 02	9.4999990D-08	9.9999991D-11	1.0000000D-10	9.4999995D-08	9.4999995D-08

CHARACTERISTICS FOR SET NO. = 18

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
5.0000000D 01	1.9599901D-12	7.8399693D-14	7.8399693D-14	1.9599923D-12	1.9599923D-12
1.0000000D 02	7.8399605D-12	1.5679917D-13	1.5679917D-13	7.8399638D-12	7.8399638D-12
1.5000000D 02	1.7639911D-11	2.3519842D-13	2.3519842D-13	1.7639903D-11	1.7639903D-11
2.0000000D 02	3.1359810D-11	3.1359730D-13	3.1359730D-13	3.1359796D-11	3.1359796D-11
2.5000000D 02	4.8999615D-11	3.9199571D-13	3.9199572D-13	4.8999622D-11	4.8999622D-11
3.0000000D 02	7.0559366D-11	4.7039391D-13	4.7039391D-13	7.0559362D-11	7.0559362D-11
3.5000000D 02	9.6039046D-11	5.4879190D-13	5.4879190D-13	9.6039008D-11	9.6039008D-11
4.0000000D 02	1.0160521D-10	5.6447099D-13	5.6447099D-13	1.2387058D-10	1.2387057D-10
4.5000000D 02	1.0160499D-10	5.6447040D-13	5.6447040D-13	1.5209411D-10	1.5209410D-10
5.0000000D 02	1.0160478D-10	5.6446981D-13	5.6446981D-13	1.8031762D-10	1.8031761D-10
5.5000000D 02	1.0160489D-10	5.6446929D-13	5.6446929D-13	2.0854110D-10	2.0854109D-10
6.0000000D 02	1.0160452D-10	5.6446909D-13	5.6446909D-13	2.3676456D-10	2.3676455D-10
6.5000000D 02	1.0160445D-10	5.6446890D-13	5.6446890D-13	2.6498801D-10	2.6498800D-10
7.0000000D 02	1.0160438D-10	5.6446870D-13	5.6446870D-13	2.9321145D-10	2.9321144D-10
7.5000000D 02	1.0160435D-10	5.6446862D-13	5.6446862D-13	3.2143488D-10	3.2143488D-10
8.0000000D 02	1.0160438D-10	5.6446862D-13	5.6446862D-13	3.4965831D-10	3.4965830D-10
8.5000000D 02	1.0160435D-10	5.6446862D-13	5.6446862D-13	3.7788174D-10	3.7788174D-10
9.0000000D 02	1.0160435D-10	5.6446862D-13	5.6446862D-13	4.0610517D-10	4.0610516D-10
9.5000000D 02	1.0160435D-10	5.6446862D-13	5.6446862D-13	4.3432860D-10	4.3432860D-10

CHARACTERISTICS FOR SET NO. = 19

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
5.0000000D 01	2.4344678D-08	9.7405877D-10	9.7405879D-10	2.4351469D-08	2.4351470D-08
1.0000000D 02	9.7378710D-08	1.9474481D-09	1.9474483D-09	9.7389140D-08	9.7389141D-08
1.5000000D 02	2.1910210D-07	2.9201679D-09	2.9201685D-09	2.1907954D-07	2.1907954D-07
2.0000000D 02	3.8942380D-07	3.8917642D-09	3.8917657D-09	3.8937784D-07	3.8937785D-07
2.5000000D 02	6.0820039D-07	4.8619384D-09	4.8610413D-09	6.0822041D-07	6.0822041D-07
3.0000000D 02	8.7564526D-07	5.8314447D-09	5.8314498D-09	8.7555498D-07	8.7555499D-07
3.5000000D 02	1.1914584D-06	6.8002832D-09	6.8002913D-09	1.1913482D-06	1.1913482D-06
4.0000000D 02	1.3999645D-06	7.3806017D-09	7.3806121D-09	1.5458703D-06	1.5458703D-06
4.5000000D 02	1.3992436D-06	7.3787980D-09	7.3788083D-09	1.9148553D-06	1.9140552D-06
5.0000000D 02	1.3985228D-06	7.3769842D-09	7.3770045D-09	2.2837501D-06	2.2837497D-06
5.5000000D 02	1.3978932D-06	7.3754173D-09	7.3764276D-09	2.6525604D-06	2.6525596D-06
6.0000000D 02	1.3976287D-06	7.3747480D-09	7.3747583D-09	3.0213145D-06	3.0213132D-06
6.5000000D 02	1.3973903D-06	7.3741515D-09	7.3741618D-09	3.3900370D-06	3.3900350D-06
7.0000000D 02	1.3971520D-06	7.3735549D-09	7.3735652D-09	3.7587297D-06	3.7587269D-06
7.5000000D 02	1.3970495D-06	7.3732963D-09	7.3733066D-09	4.1274009D-06	4.1273972D-06
8.0000000D 02	1.3970377D-06	7.3732630D-09	7.3732733D-09	4.4960649D-06	4.4960601D-06
8.5000000D 02	1.3970389D-06	7.3732661D-09	7.3732764D-09	4.8647282D-06	4.8647221D-06
9.0000000D 02	1.3970402D-06	7.3732692D-09	7.3732795D-09	5.2333915D-06	5.2333842D-06
9.5000000D 02	1.3970403D-06	7.3732696D-09	7.3732799D-09	5.6020550D-06	5.6020462D-06

SYSTEM INFORMATION-UPPER BOUNDS

DIFFERENTIAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	Q	W	L
0.0	0.0	1.55488600D-04	1.55488600D-04
5.00000000D 01	6.25897798D-03	1.55314416D-04	1.56292648D-04
1.00000000D 02	1.24726386D-02	1.55140680D-04	1.57100134D-04
1.50000000D 02	1.86560952D-02	1.54966945D-04	1.57912984D-04
2.00000000D 02	2.47941622D-02	1.54793662D-04	1.58729220D-04
2.50000000D 02	3.08881210D-02	1.54620813D-04	1.59548981D-04
3.00000000D 02	3.69524750D-02	1.54447964D-04	1.60374167D-04
3.50000000D 02	4.16343456D-02	1.54314313D-04	1.61018200D-04
4.00000000D 02	4.25772861D-02	1.54289003D-04	1.61150347D-04
4.50000000D 02	4.25350887D-02	1.54290330D-04	1.61144631D-04
5.00000000D 02	4.24988613D-02	1.54291492D-04	1.61139698D-04
5.50000000D 02	4.24667712D-02	1.54292509D-04	1.61136410D-04
6.00000000D 02	4.24539224D-02	1.54292943D-04	1.61133701D-04
6.50000000D 02	4.24438836D-02	1.54293296D-04	1.61132380D-04
7.00000000D 02	4.24338446D-02	1.54293649D-04	1.61131059D-04
7.50000000D 02	4.24307950D-02	1.54293787D-04	1.61130690D-04
8.00000000D 02	4.24323814D-02	1.54293782D-04	1.61130952D-04
8.50000000D 02	4.24339712D-02	1.54293778D-04	1.61131215D-04
9.00000000D 02	4.24355611D-02	1.54293773D-04	1.61131478D-04
9.50000000D 02	4.24370216D-02	1.54293772D-04	1.61131723D-04

INTEGRAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	WSUM	FSUM
5.00000000D 01	7.77007539D-03	7.76423261D-03
1.00000000D 02	1.55314528D-02	1.55076463D-02
1.50000000D 02	2.32841434D-02	2.32306983D-02
2.00000000D 02	3.10281586D-02	3.09322323D-02
2.50000000D 02	3.87635205D-02	3.86124648D-02
3.00000000D 02	4.64902399D-02	4.62710506D-02
3.50000000D 02	5.42092968D-02	5.39033780D-02
4.00000000D 02	6.19243797D-02	6.14928377D-02
4.50000000D 02	6.96388630D-02	6.90243685D-02
5.00000000D 02	7.73534086D-02	7.64951929D-02
5.50000000D 02	8.50680086D-02	8.39058646D-02
6.00000000D 02	9.27826449D-02	9.12569331D-02
6.50000000D 02	1.00497301D-01	9.85489456D-02
7.00000000D 02	1.08211974D-01	1.05782386D-01
7.50000000D 02	1.15926660D-01	1.12957746D-01
8.00000000D 02	1.23641350D-01	1.20075528D-01
8.50000000D 02	1.31356039D-01	1.27136206D-01
9.00000000D 02	1.39070727D-01	1.34140240D-01
9.50000000D 02	1.46785416D-01	1.41088083D-01

18. APPENDIX F: KITT-1 OUTPUT RESULTS FOR CHRS FAULT TREE

Because of the similarities of the KITT-1 output for the three cases (WASH-1400, LERs and NUREG), only a sample from the KITT-1 output results for the first case is given here (see pages 318-336).

Tables for quick translation of the KITT-1 output are not given here, but those tables given in Appendix E could be used.

```
**********************************************************************************************************************
* PROBLEM TITLE FOR THIS ANALYSIS BY KITT-1. SAFTY ANALYSIS PROBLEM FOR CONVERSION CHECKING                            *
**********************************************************************************************************************

NO. OF PARAMETER RUNS (NPROB) =   1

NO. OF COMPONENTS AND INHIBIT CONDITIONS (NCOMP) =  18


                              COMPONENT DATA (LAMBDA AND TAU)
                             (NON-POSITIVE TAU DENOTES NON-REPAIR)
                          (NON-POSITIVE LAMBDA DENOTES INHIBIT CONDITION)

           COMPONENT INDEX                  LAMBDA                      TAU
                         1          1.600000000D-06         4.000000000D 01
                         2          1.600000000D-08         2.800000000D 01
                         3          2.600000000D-07         2.800000000D 01
                         4          1.600000000D-06         4.000000000D 01
                         5          1.600000000D-08         2.800000000D 01
                         6          2.600000000D-08         2.800000000D 01
                         7          1.200000000D-06         9.000000000D 01
                         8          1.100000000D-05         3.800000000D 01
                         9          1.200000000D-06         9.000000000D 01
                        10          1.100000000D-05         3.800000000D 01
                        11          1.100000000D-06         3.000000000D 01
                        12          1.200000000D-05         5.000000000D-01
                        13          1.300000000D-06         3.000000000D 01
                        14          1.000000000D-10         2.400000000D 01
                        15          1.030000000D-05         5.000000000D-01
                        16          1.250000000D-06         3.600000000D 02
                        17          2.000000000D-05         5.000000000D-01
                        18          1.000000000D-10         3.600000000D 02


BRACKET FLAG (ISTOP). IF ISTOP=2 SYSTEM INFORMATION IS OBTAINED FROM BRACKETING. IF ISTOP=1 IT IS NOT.
FOR THIS PROBLEM ISTOP = 2


NO. OF TIME POINTS (NTPT) =  20
PRINT OUT MULTIPLE (NOUT) =   1
MESH SIZE (DELTA) = 3.000000000D 01 HOURS


NUMBER OF OUTER BRACKETS (NBMAX) =   10
FAILURE RATE CORRECTION FLAG (IFAG2) = 2


INNER BRACKETS FOR IFAG2=2
OUTER BRACKET NO. (M)     NO. OF INNER BRACKETS (NB2(M))
          1                            10
          2                             9
          3                             8
```

```
         4                              7
         5                              6
         6                              5
         7                              4
         8                              3
         9                              2
        10                              1

SET FLAG (IPATH). IF IPATH=1 MINIMAL CUT SETS ARE USED. IF IPATH=2 MINIMAL PATH SETS ARE USED.
FOR THIS PROBLEM IPATH = 1

NO. OF SETS (NCUT) =    31

SET INFORMATION

SET NO.   1. WITH COMPONENTS -   17

SET NO.   2. WITH COMPONENTS -   18

SET NO.   3. WITH COMPONENTS -    7    1

SET NO.   4. WITH COMPONENTS -    7    2

SET NO.   5. WITH COMPONENTS -    7    3

SET NO.   6. WITH COMPONENTS -    7    4

SET NO.   7. WITH COMPONENTS -    7    5

SET NO.   8. WITH COMPONENTS -    7    6

SET NO.   9. WITH COMPONENTS -    8    1

SET NO.  10. WITH COMPONENTS -    8    2

SET NO.  11. WITH COMPONENTS -    8    3

SET NO.  12. WITH COMPONENTS -    8    4

SET NO.  13. WITH COMPONENTS -    8    5

SET NO.  14. WITH COMPONENTS -    8    6

SET NO.  15. WITH COMPONENTS -    9    1

SET NO.  16. WITH COMPONENTS -    9    2

SET NO.  17. WITH COMPONENTS -    9    3

SET NO.  18. WITH COMPONENTS -    9    4

SET NO.  19. WITH COMPONENTS -    9    5

SET NO.  20. WITH COMPONENTS -    9    6

SET NO.  21. WITH COMPONENTS -   10    1
```

SET NO. 22, WITH COMPONENTS -	10	2
SET NO. 23, WITH COMPONENTS -	10	3
SET NO. 24, WITH COMPONENTS -	10	4
SET NO. 25, WITH COMPONENTS -	10	5
SET NO. 26, WITH COMPONENTS -	10	6
SET NO. 27, WITH COMPONENTS -	16	11
SET NO. 28, WITH COMPONENTS -	16	12
SET NO. 29, WITH COMPONENTS -	16	13
SET NO. 30, WITH COMPONENTS -	16	14
SET NO. 31, WITH COMPONENTS -	16	15

COMPONENT AND INHIBIT INFORMATION

CHARACTERISTICS FOR COMPONENT NO. = 1

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.6000000D-06	1.6000000D-06	0.0	0.0
3.0000000D 01	4.7998720D-05	1.5999232D-06	1.6000000D-06	4.7998848D-05	4.7998848D-05
6.0000000D 01	6.3996416D-05	1.5998976D-06	1.6000000D-06	9.5996160D-05	9.5995392D-05
9.0000000D 01	6.3995904D-05	1.5998976D-06	1.6000000D-06	1.4399309D-04	1.4398963D-04
1.2000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	1.9199002D-04	1.9198157D-04
1.5000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	2.3998694D-04	2.3997120D-04
1.8000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	2.8798387D-04	2.8795853D-04
2.1000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	3.3598080D-04	3.3594356D-04
2.4000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	3.8397773D-04	3.8392628D-04
2.7000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	4.3197466D-04	4.3190670D-04
3.0000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	4.7997159D-04	4.7988482D-04
3.3000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	5.2796851D-04	5.2786063D-04
3.6000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	5.7596544D-04	5.7583414D-04
3.9000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	6.2396237D-04	6.2380535D-04
4.2000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	6.7195930D-04	6.7177426D-04
4.5000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	7.1995623D-04	7.1974086D-04
4.8000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	7.6795315D-04	7.6770516D-04
5.1000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	8.1595008D-04	8.1566716D-04
5.4000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	8.6394701D-04	8.6362686D-04
5.7000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	9.1194394D-04	9.1158425D-04

CHARACTERISTICS FOR COMPONENT NO. = 2

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.6000000D-08	1.6000000D-08	0.0	0.0
3.0000000D 01	4.4799989D-07	1.5999993D-08	1.6000000D-08	4.7999989D-07	4.7999988D-07
6.0000000D 01	4.4799980D-07	1.5999993D-08	1.6000000D-08	9.5999968D-07	9.5999954D-07
9.0000000D 01	4.4799980D-07	1.5999993D-08	1.6000000D-08	1.4399995D-06	1.4399990D-06
1.2000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	1.9199992D-06	1.9199982D-06
1.5000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	2.3999990D-06	2.3999971D-06
1.8000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	2.8799988D-06	2.8799959D-06
2.1000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	3.3599986D-06	3.3599944D-06
2.4000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	3.8399984D-06	3.8399926D-06
2.7000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	4.3199982D-06	4.3199907D-06
3.0000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	4.7999980D-06	4.7999885D-06
3.3000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	5.2799977D-06	5.2799861D-06
3.6000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	5.7599975D-06	5.7599834D-06
3.9000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	6.2399973D-06	6.2399805D-06
4.2000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	6.7199971D-06	6.7199774D-06
4.5000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	7.1999969D-06	7.1999741D-06
4.8000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	7.6799967D-06	7.6799705D-06
5.1000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	8.1599965D-06	8.1599667D-06
5.4000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	8.6399962D-06	8.6399627D-06
5.7000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	9.1199960D-06	9.1199584D-06

CHARACTERISTICS FOR COMPONENT NO. = 3

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	2.6000000D-07	2.6000000D-07	0.0	0.0
3.0000000D 01	7.2799707D-06	2.5999811D-07	2.6000000D-07	7.7999716D-06	7.7999696D-06
6.0000000D 01	7.2799470D-06	2.5999811D-07	2.6000000D-07	1.5599915D-05	1.5599878D-05
9.0000000D 01	7.2799470D-06	2.5999811D-07	2.6000000D-07	2.3399858D-05	2.3399726D-05

1.2000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	3.1199801D-05	3.1199513D-05
1.5000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	3.8999744D-05	3.8999240D-05
1.8000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	4.6799688D-05	4.6798905D-05
2.1000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	5.4599631D-05	5.4598509D-05
2.4000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	6.2399574D-05	6.2398053D-05
2.7000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	7.0199517D-05	7.0197536D-05
3.0000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	7.7999461D-05	7.7996958D-05
3.3000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	8.5799404D-05	8.5796319D-05
3.6000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	9.3599347D-05	9.3595620D-05
3.9000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	1.0139929D-04	1.0139486D-04
4.2000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	1.0919923D-04	1.0919404D-04
4.5000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	1.1699918D-04	1.1699316D-04
4.8000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	1.2479912D-04	1.2479221D-04
5.1000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	1.3259906D-04	1.3259121D-04
5.4000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	1.4039901D-04	1.4039014D-04
5.7000000D 02	7.2799470D-06	2.5999811D-07	2.6000000D-07	1.4819895D-04	1.4818902D-04

CHARACTERISTICS FOR COMPONENT NO. = 4

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.6000000D-06	1.6000000D-06	0.0	0.0
3.0000000D 01	4.7998720D-05	1.5999232D-06	1.6000000D-06	4.7998848D-05	4.7998848D-05
6.0000000D 01	6.3996416D-05	1.5998976D-06	1.6000000D-06	9.5996160D-05	9.5995392D-05
9.0000000D 01	6.3995904D-05	1.5998976D-06	1.6000000D-06	1.4399309D-04	1.4398963D-04
1.2000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	1.9199002D-04	1.9198157D-04
1.5000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	2.3998694D-04	2.3997120D-04
1.8000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	2.8798387D-04	2.8795853D-04
2.1000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	3.3598080D-04	3.3594356D-04
2.4000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	3.8397773D-04	3.8392628D-04
2.7000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	4.3197466D-04	4.3190670D-04
3.0000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	4.7997159D-04	4.7988482D-04
3.3000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	5.2796851D-04	5.2786063D-04
3.6000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	5.7596544D-04	5.7583414D-04
3.9000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	6.2396237D-04	6.2380535D-04
4.2000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	6.7195930D-04	6.7177426D-04
4.5000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	7.1995623D-04	7.1974086D-04
4.8000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	7.6795315D-04	7.6770516D-04
5.1000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	8.1595008D-04	8.1566716D-04
5.4000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	8.6394701D-04	8.6362686D-04
5.7000000D 02	6.3995904D-05	1.5998976D-06	1.6000000D-06	9.1194394D-04	9.1158425D-04

CHARACTERISTICS FOR COMPONENT NO. = 5

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.6000000D-08	1.6000000D-08	0.0	0.0
3.0000000D 01	4.4799989D-07	1.5999993D-08	1.6000000D-08	4.7999989D-07	4.7999988D-07
6.0000000D 01	4.4799980D-07	1.5999993D-08	1.6000000D-08	9.5999968D-07	9.5999954D-07
9.0000000D 01	4.4799980D-07	1.5999993D-08	1.6000000D-08	1.4399995D-06	1.4399990D-06
1.2000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	1.9199992D-06	1.9199982D-06
1.5000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	2.3999990D-06	2.3999971D-06
1.8000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	2.8799988D-06	2.8799959D-06
2.1000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	3.3599986D-06	3.3599944D-06
2.4000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	3.8399984D-06	3.8399926D-06
2.7000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	4.3199982D-06	4.3199907D-06
3.0000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	4.7999980D-06	4.7999885D-06
3.3000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	5.2799977D-06	5.2799861D-06
3.6000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	5.7599975D-06	5.7599834D-06
3.9000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	6.2399973D-06	6.2399805D-06

4.2000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	6.7199971D-06	6.7199774D-06
4.5000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	7.1999969D-06	7.1999741D-06
4.8000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	7.6799967D-06	7.6799705D-06
5.1000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	8.1599965D-06	8.1599667D-06
5.4000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	8.6399962D-06	8.6399627D-06
5.7000000D 02	4.4799980D-07	1.5999993D-08	1.6000000D-08	9.1199960D-06	9.1199584D-06

CHARACTERISTICS FOR COMPONENT NO. = 6

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	2.6000000D-08	2.6000000D-08	0.0	0.0
3.0000000D 01	7.2799971D-07	2.5999981D-08	2.6000000D-08	7.7999972D-07	7.7999970D-07
6.0000000D 01	7.2799947D-07	2.5999981D-08	2.6000000D-08	1.5599991D-06	1.5599988D-06
9.0000000D 01	7.2799947D-07	2.5999981D-08	2.6000000D-08	2.3399986D-06	2.3399973D-06
1.2000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	3.1199980D-06	3.1199951D-06
1.5000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	3.8999974D-06	3.8999924D-06
1.8000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	4.6799969D-06	4.6799890D-06
2.1000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	5.4599963D-06	5.4599851D-06
2.4000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	6.2399957D-06	6.2399805D-06
2.7000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	7.0199952D-06	7.0199754D-06
3.0000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	7.7999946D-06	7.7999696D-06
3.3000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	8.5799940D-06	8.5799632D-06
3.6000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	9.3599935D-06	9.3599562D-06
3.9000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	1.0139993D-05	1.0139949D-05
4.2000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	1.0919992D-05	1.0919940D-05
4.5000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	1.1699992D-05	1.1699932D-05
4.8000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	1.2479991D-05	1.2479922D-05
5.1000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	1.3259991D-05	1.3259912D-05
5.4000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	1.4039990D-05	1.4039901D-05
5.7000000D 02	7.2799947D-07	2.5999981D-08	2.6000000D-08	1.4819989D-05	1.4819890D-05

CHARACTERISTICS FOR COMPONENT NO. = 7

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.2000000D-06	1.2000000D-06	0.0	0.0
3.0000000D 01	3.5999028D-05	1.1999568D-06	1.2000000D-06	3.5999352D-05	3.5999352D-05
6.0000000D 01	7.1997084D-05	1.1999136D-06	1.2000000D-06	7.1997408D-05	7.1997408D-05
9.0000000D 01	1.0799417D-04	1.1998704D-06	1.2000000D-06	1.0799417D-04	1.0799417D-04
1.2000000D 02	1.0799125D-04	1.1998704D-06	1.2000000D-06	1.4399028D-04	1.4398963D-04
1.5000000D 02	1.0798931D-04	1.1998704D-06	1.2000000D-06	1.7998639D-04	1.7998380D-04
1.8000000D 02	1.0798834D-04	1.1998704D-06	1.2000000D-06	2.1598251D-04	2.1597667D-04
2.1000000D 02	1.0798834D-04	1.1998704D-06	1.2000000D-06	2.5197862D-04	2.5196825D-04
2.4000000D 02	1.0798834D-04	1.1998704D-06	1.2000000D-06	2.8797473D-04	2.8795853D-04
2.7000000D 02	1.0798834D-04	1.1998704D-06	1.2000000D-06	3.2397084D-04	3.2394752D-04
3.0000000D 02	1.0798834D-04	1.1998704D-06	1.2000000D-06	3.5996695D-04	3.5993521D-04
3.3000000D 02	1.0798834D-04	1.1998704D-06	1.2000000D-06	3.9596307D-04	3.9592160D-04
3.6000000D 02	1.0798834D-04	1.1998704D-06	1.2000000D-06	4.3195918D-04	4.3190670D-04
3.9000000D 02	1.0798834D-04	1.1998704D-06	1.2000000D-06	4.6795529D-04	4.6789051D-04
4.2000000D 02	1.0798834D-04	1.1998704D-06	1.2000000D-06	5.0395140D-04	5.0387301D-04
4.5000000D 02	1.0798834D-04	1.1998704D-06	1.2000000D-06	5.3994752D-04	5.3985423D-04
4.8000000D 02	1.0798834D-04	1.1998704D-06	1.2000000D-06	5.7594363D-04	5.7583414D-04
5.1000000D 02	1.0798834D-04	1.1998704D-06	1.2000000D-06	6.1193974D-04	6.1181277D-04
5.4000000D 02	1.0798834D-04	1.1998704D-06	1.2000000D-06	6.4793585D-04	6.4779009D-04
5.7000000D 02	1.0798834D-04	1.1998704D-06	1.2000000D-06	6.8393197D-04	6.8376613D-04

CHARACTERISTICS FOR COMPONENT NO. = 8

2.7000000D 02	4.1782535D-04	1.0995404D-05	1.1000000D-05	2.9688570D-03	2.9655939D-03
3.0000000D 02	4.1782535D-04	1.0995404D-05	1.1000000D-05	3.2987191D-03	3.2945610D-03
3.3000000D 02	4.1782535D-04	1.0995404D-05	1.1000000D-05	3.6285812D-03	3.6234195D-03
3.6000000D 02	4.1782535D-04	1.0995404D-05	1.1000000D-05	3.9584433D-03	3.9521695D-03
3.9000000D 02	4.1782535D-04	1.0995404D-05	1.1000000D-05	4.2883055D-03	4.2808111D-03
4.2000000D 02	4.1782535D-04	1.0995404D-05	1.1000000D-05	4.6181676D-03	4.6093442D-03
4.5000000D 02	4.1782535D-04	1.0995404D-05	1.1000000D-05	4.9480297D-03	4.9377689D-03
4.8000000D 02	4.1782535D-04	1.0995404D-05	1.1000000D-05	5.2778918D-03	5.2660853D-03
5.1000000D 02	4.1782535D-04	1.0995404D-05	1.1000000D-05	5.6077539D-03	5.5942933D-03
5.4000000D 02	4.1782535D-04	1.0995404D-05	1.1000000D-05	5.9376161D-03	5.9223931D-03
5.7000000D 02	4.1782535D-04	1.0995404D-05	1.1000000D-05	6.2674782D-03	6.2503846D-03

CHARACTERISTICS FOR COMPONENT NO. = 11

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.1000000D-06	1.1000000D-06	0.0	0.0
3.0000000D 01	3.2999456D-05	1.0999637D-06	1.1000000D-06	3.2999456D-05	3.2999456D-05
6.0000000D 01	3.2998911D-05	1.0999637D-06	1.1000000D-06	6.5998367D-05	6.5997822D-05
9.0000000D 01	3.2998911D-05	1.0999637D-06	1.1000000D-06	9.8997279D-05	9.8995100D-05
1.2000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	1.3199619D-04	1.3199129D-04
1.5000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	1.6499510D-04	1.6498639D-04
1.8000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	1.9799401D-04	1.9798040D-04
2.1000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	2.3099292D-04	2.3097332D-04
2.4000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	2.6399183D-04	2.6396516D-04
2.7000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	2.9699074D-04	2.9695590D-04
3.0000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	3.2998965D-04	3.2994556D-04
3.3000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	3.6298857D-04	3.6293412D-04
3.6000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	3.9598748D-04	3.9592160D-04
3.9000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	4.2898639D-04	4.2890799D-04
4.2000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	4.6198530D-04	4.6189329D-04
4.5000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	4.9498421D-04	4.9487751D-04
4.8000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	5.2798312D-04	5.2786063D-04
5.1000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	5.6098203D-04	5.6084267D-04
5.4000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	5.9398094D-04	5.9382362D-04
5.7000000D 02	3.2998911D-05	1.0999637D-06	1.1000000D-06	6.2697985D-04	6.2680348D-04

CHARACTERISTICS FOR COMPONENT NO. = 12

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.2000000D-05	1.2000000D-05	0.0	0.0
3.0000000D 01	5.9999640D-06	1.1999928D-05	1.2000000D-05	3.5999892D-04	3.5993521D-04
6.0000000D 01	5.9999640D-06	1.1999928D-05	1.2000000D-05	7.1999676D-04	7.1974086D-04
9.0000000D 01	5.9999640D-06	1.1999928D-05	1.2000000D-05	1.0799946D-03	1.0794170D-03
1.2000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	1.4399924D-03	1.4389637D-03
1.5000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	1.7999903D-03	1.7983810D-03
1.8000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	2.1599881D-03	2.1576689D-03
2.1000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	2.5199860D-03	2.5168275D-03
2.4000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	2.8799838D-03	2.8758568D-03
2.7000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	3.2399816D-03	3.2347569D-03
3.0000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	3.5999795D-03	3.5935278D-03
3.3000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	3.9599773D-03	3.9521695D-03
3.6000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	4.3199752D-03	4.3106822D-03
3.9000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	4.6799730D-03	4.6690659D-03
4.2000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	5.0399708D-03	5.0273205D-03
4.5000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	5.3999687D-03	5.3854462D-03
4.8000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	5.7599665D-03	5.7434430D-03
5.1000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	6.1199644D-03	6.1013109D-03
5.4000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	6.4799622D-03	6.4590501D-03

5.7000000D 02	5.9999640D-06	1.1999928D-05	1.2000000D-05	6.8399600D-03	6.8166604D-03

CHARACTERISTICS FOR COMPONENT NO. = 13

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.3000000D-06	1.3000000D-06	0.0	0.0
3.0000000D 01	3.8999240D-05	1.2999493D-06	1.3000000D-06	3.8999240D-05	3.8999240D-05
6.0000000D 01	3.8998479D-05	1.2999493D-06	1.3000000D-06	7.7997719D-05	7.7996958D-05
9.0000000D 01	3.8998479D-05	1.2999493D-06	1.3000000D-06	1.1699620D-04	1.1699316D-04
1.2000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	1.5599468D-04	1.5598783D-04
1.5000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	1.9499316D-04	1.9498099D-04
1.8000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	2.3399163D-04	2.3397262D-04
2.1000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	2.7299011D-04	2.7296274D-04
2.4000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	3.1198859D-04	3.1195133D-04
2.7000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	3.5098707D-04	3.5093841D-04
3.0000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	3.8998555D-04	3.8992396D-04
3.3000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	4.2898403D-04	4.2890799D-04
3.6000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	4.6798251D-04	4.6789051D-04
3.9000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	5.0698099D-04	5.0687150D-04
4.2000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	5.4597947D-04	5.4585097D-04
4.5000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	5.8497795D-04	5.8482892D-04
4.8000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	6.2397643D-04	6.2380535D-04
5.1000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	6.6297490D-04	6.6278026D-04
5.4000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	7.0197338D-04	7.0175366D-04
5.7000000D 02	3.8998479D-05	1.2999493D-06	1.3000000D-06	7.4097186D-04	7.4072553D-04

CHARACTERISTICS FOR COMPONENT NO. = 14

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.0000000D-10	1.0000000D-10	0.0	0.0
3.0000000D 01	2.4000000D-09	1.0000000D-10	1.0000000D-10	3.0000000D-09	3.0000000D-09
6.0000000D 01	2.4000000D-09	1.0000000D-10	1.0000000D-10	6.0000000D-09	6.0000000D-09
9.0000000D 01	2.4000000D-09	1.0000000D-10	1.0000000D-10	9.0000000D-09	8.9999999D-09
1.2000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	1.2000000D-08	1.2000000D-08
1.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	1.5000000D-08	1.5000000D-08
1.8000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	1.8000000D-08	1.8000000D-08
2.1000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	2.1000000D-08	2.1000000D-08
2.4000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	2.4000000D-08	2.4000000D-08
2.7000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	2.7000000D-08	2.7000000D-08
3.0000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	3.0000000D-08	3.0000000D-08
3.3000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	3.3000000D-08	3.2999999D-08
3.6000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	3.6000000D-08	3.5999999D-08
3.9000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	3.9000000D-08	3.8999999D-08
4.2000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	4.2000000D-08	4.1999999D-08
4.5000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	4.5000000D-08	4.4999999D-08
4.8000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	4.8000000D-08	4.7999999D-08
5.1000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	5.1000000D-08	5.0999999D-08
5.4000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	5.4000000D-08	5.3999998D-08
5.7000000D 02	2.4000000D-09	1.0000000D-10	1.0000000D-10	5.7000000D-08	5.6999998D-08

CHARACTERISTICS FOR COMPONENT NO. = 15

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.0300000D-05	1.0300000D-05	0.0	0.0
3.0000000D 01	5.1499735D-06	1.0299947D-05	1.0300000D-05	3.0899920D-04	3.0895226D-04
6.0000000D 01	5.1499735D-06	1.0299947D-05	1.0300000D-05	6.1799761D-04	6.1780908D-04
9.0000000D 01	5.1499735D-06	1.0299947D-05	1.0300000D-05	9.2699602D-04	9.2657047D-04

1.2000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	1.2359944D-03	1.2352365D-03
1.5000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	1.5449928D-03	1.5438071D-03
1.8000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	1.8539912D-03	1.8522824D-03
2.1000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	2.1629897D-03	2.1606624D-03
2.4000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	2.4719881D-03	2.4689471D-03
2.7000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	2.7809865D-03	2.7771366D-03
3.0000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	3.0899849D-03	3.0852309D-03
3.3000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	3.3989833D-03	3.3932299D-03
3.6000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	3.7079817D-03	3.7011339D-03
3.9000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	4.0169801D-03	4.0089426D-03
4.2000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	4.3259785D-03	4.3166563D-03
4.5000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	4.6349769D-03	4.6242750D-03
4.8000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	4.9439753D-03	4.9317985D-03
5.1000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	5.2529737D-03	5.2392271D-03
5.4000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	5.5619722D-03	5.5465607D-03
5.7000000D 02	5.1499735D-06	1.0299947D-05	1.0300000D-05	5.8709706D-03	5.8537994D-03

CHARACTERISTICS FOR COMPONENT NO. = 16

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.2500000D-06	1.2500000D-06	0.0	0.0
3.0000000D 01	3.7495782D-05	1.2499531D-06	1.2500000D-06	3.7499297D-05	3.7499297D-05
6.0000000D 01	7.4991563D-05	1.2499063D-06	1.2500000D-06	7.4997188D-05	7.4997188D-05
9.0000000D 01	1.1248734D-04	1.2498594D-06	1.2500000D-06	1.1249367D-04	1.1249367D-04
1.2000000D 02	1.4998313D-04	1.2498125D-06	1.2500000D-06	1.4998875D-04	1.4998875D-04
1.5000000D 02	1.8747891D-04	1.2497657D-06	1.2500000D-06	1.8748242D-04	1.8748242D-04
1.8000000D 02	2.2497469D-04	1.2497188D-06	1.2500000D-06	2.2497469D-04	2.2497469D-04
2.1000000D 02	2.6246204D-04	1.2496719D-06	1.2500000D-06	2.6246555D-04	2.6246555D-04
2.4000000D 02	2.9994938D-04	1.2496251D-06	1.2500000D-06	2.9995501D-04	2.9995500D-04
2.7000000D 02	3.3743673D-04	1.2495782D-06	1.2500000D-06	3.3744305D-04	3.3744305D-04
3.0000000D 02	3.7492407D-04	1.2495313D-06	1.2500000D-06	3.7492970D-04	3.7492970D-04
3.3000000D 02	4.1241142D-04	1.2494845D-06	1.2500000D-06	4.1241494D-04	4.1241493D-04
3.6000000D 02	4.4989877D-04	1.2494376D-06	1.2500000D-06	4.4989877D-04	4.4989877D-04
3.9000000D 02	4.4988611D-04	1.2494376D-06	1.2500000D-06	4.8738190D-04	4.8738119D-04
4.2000000D 02	4.4987346D-04	1.2494377D-06	1.2500000D-06	5.2486503D-04	5.2486221D-04
4.5000000D 02	4.4986081D-04	1.2494377D-06	1.2500000D-06	5.6234816D-04	5.6234183D-04
4.8000000D 02	4.4984816D-04	1.2494377D-06	1.2500000D-06	5.9983129D-04	5.9982004D-04
5.1000000D 02	4.4983551D-04	1.2494377D-06	1.2500000D-06	6.3731442D-04	6.3729684D-04
5.4000000D 02	4.4982286D-04	1.2494377D-06	1.2500000D-06	6.7479755D-04	6.7477224D-04
5.7000000D 02	4.4981864D-04	1.2494377D-06	1.2500000D-06	7.1228068D-04	7.1224623D-04

CHARACTERISTICS FOR COMPONENT NO. = 17

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	2.0000000D-05	2.0000000D-05	0.0	0.0
3.0000000D 01	9.9999000D-06	1.9999800D-05	2.0000000D-05	5.9999700D-04	5.9982004D-04
6.0000000D 01	9.9999000D-06	1.9999800D-05	2.0000000D-05	1.1999910D-03	1.1992803D-03
9.0000000D 01	9.9999000D-06	1.9999800D-05	2.0000000D-05	1.7999850D-03	1.7983810D-03
1.2000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	2.3999790D-03	2.3971223D-03
1.5000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	2.9999730D-03	2.9955045D-03
1.8000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	3.5999670D-03	3.5935278D-03
2.1000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	4.1999610D-03	4.1911923D-03
2.4000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	4.7999550D-03	4.7884984D-03
2.7000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	5.3999490D-03	5.3854462D-03
3.0000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	5.9999430D-03	5.9820359D-03
3.3000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	6.5999370D-03	6.5782678D-03
3.6000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	7.1999310D-03	7.1741421D-03
3.9000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	7.7999250D-03	7.7696589D-03

MINIMAL SET INFORMATION

CHARACTERISTICS FOR SET NO. = 1

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	2.0000000D-05	2.0000000D-05	0.0	0.0
3.0000000D 01	9.9999000D-06	1.9999800D-05	2.0000000D-05	5.9999700D-04	5.9982004D-04
6.0000000D 01	9.9999000D-06	1.9999800D-05	2.0000000D-05	1.1999910D-03	1.1992803D-03
9.0000000D 01	9.9999000D-06	1.9999800D-05	2.0000000D-05	1.7999850D-03	1.7983810D-03
1.2000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	2.3999790D-03	2.3971223D-03
1.5000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	2.9999730D-03	2.9955045D-03
1.8000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	3.5999670D-03	3.5935278D-03
2.1000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	4.1999610D-03	4.1911923D-03
2.4000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	4.7999550D-03	4.7884984D-03
2.7000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	5.3999490D-03	5.3854462D-03
3.0000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	5.9999430D-03	5.9820359D-03
3.3000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	6.5999370D-03	6.5782678D-03
3.6000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	7.1999310D-03	7.1741421D-03
3.9000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	7.7999250D-03	7.7696589D-03
4.2000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	8.3999190D-03	8.3648186D-03
4.5000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	8.9999130D-03	8.9596212D-03
4.8000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	9.5999070D-03	9.5540671D-03
5.1000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	1.0199901D-02	1.0148156D-02
5.4000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	1.0799895D-02	1.0741889D-02
5.7000000D 02	9.9999000D-06	1.9999800D-05	2.0000000D-05	1.1399889D-02	1.1335266D-02

CHARACTERISTICS FOR SET NO. = 2

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	1.0000000D-10	1.0000000D-10	0.0	0.0
3.0000000D 01	3.0000000D-09	1.0000000D-10	1.0000000D-10	3.0000000D-09	3.0000000D-09
6.0000000D 01	5.9999999D-09	9.9999999D-11	1.0000000D-10	6.0000000D-09	6.0000000D-09
9.0000000D 01	8.9999999D-09	9.9999999D-11	1.0000000D-10	9.0000000D-09	9.0000000D-09
1.2000000D 02	1.2000000D-08	9.9999999D-11	1.0000000D-10	1.2000000D-08	1.2000000D-08
1.5000000D 02	1.5000000D-08	9.9999999D-11	1.0000000D-10	1.5000000D-08	1.5000000D-08
1.8000000D 02	1.8000000D-08	9.9999998D-11	1.0000000D-10	1.8000000D-08	1.8000000D-08
2.1000000D 02	2.1000000D-08	9.9999998D-11	1.0000000D-10	2.1000000D-08	2.1000000D-08
2.4000000D 02	2.4000000D-08	9.9999998D-11	1.0000000D-10	2.4000000D-08	2.4000000D-08
2.7000000D 02	2.7000000D-08	9.9999997D-11	1.0000000D-10	2.7000000D-08	2.7000000D-08
3.0000000D 02	3.0000000D-08	9.9999997D-11	1.0000000D-10	3.0000000D-08	3.0000000D-08
3.3000000D 02	3.2999999D-08	9.9999997D-11	1.0000000D-10	3.2999999D-08	3.2999999D-08
3.6000000D 02	3.5999999D-08	9.9999996D-11	1.0000000D-10	3.5999999D-08	3.5999999D-08
3.9000000D 02	3.5999999D-08	9.9999996D-11	1.0000000D-10	3.8999999D-08	3.8999999D-08
4.2000000D 02	3.5999999D-08	9.9999996D-11	1.0000000D-10	4.1999999D-08	4.1999999D-08
4.5000000D 02	3.5999999D-08	9.9999996D-11	1.0000000D-10	4.4999999D-08	4.4999999D-08
4.8000000D 02	3.5999999D-08	9.9999996D-11	1.0000000D-10	4.7999999D-08	4.7999999D-08
5.1000000D 02	3.5999999D-08	9.9999996D-11	1.0000000D-10	5.0999999D-08	5.0999999D-08
5.4000000D 02	3.5999999D-08	9.9999996D-11	1.0000000D-10	5.3999999D-08	5.3999999D-08
5.7000000D 02	3.5999999D-08	9.9999996D-11	1.0000000D-10	5.6999999D-08	5.6999998D-08

CHARACTERISTICS FOR SET NO. = 3

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	1.7279073D-09	1.1519207D-10	1.1519207D-10	1.7278811D-09	1.7278811D-09
6.0000000D 01	4.6075554D-09	1.9197813D-10	1.9197813D-10	6.3354341D-09	6.3354341D-09
9.0000000D 01	6.9111844D-09	2.4956640D-10	2.4956640D-10	1.2958602D-08	1.2958602D-08

1.2000000D 02	6.9109979D-09	2.4956174D-10	2.4956174D-10	2.0445524D-08	2.0445524D-08
1.5000000D 02	6.9108735D-09	2.4955863D-10	2.4955863D-10	2.7932330D-08	2.7932330D-08
1.8000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	3.5419065D-08	3.5419065D-08
2.1000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	4.2905778D-08	4.2905777D-08
2.4000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	5.0392490D-08	5.0392489D-08
2.7000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	5.7879202D-08	5.7879201D-08
3.0000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	6.5365914D-08	6.5365913D-08
3.3000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	7.2852626D-08	7.2852624D-08
3.6000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	8.0339339D-08	8.0339336D-08
3.9000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	8.7826051D-08	8.7826048D-08
4.2000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	9.5312763D-08	9.5312759D-08
4.5000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.0279948D-07	1.0279947D-07
4.8000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.1028619D-07	1.1028618D-07
5.1000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.1777290D-07	1.1777289D-07
5.4000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.2525961D-07	1.2525961D-07
5.7000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.3274632D-07	1.3274632D-07

CHARACTERISTICS FOR SET NO. = 4

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	1.6127561D-11	1.1135647D-12	1.1135647D-12	1.6703471D-11	1.6703471D-11
6.0000000D 01	3.2254679D-11	1.6895139D-12	1.6895139D-12	5.8749649D-11	5.8749649D-11
9.0000000D 01	4.8381366D-11	2.2654476D-12	2.2654476D-12	1.1807407D-10	1.1807406D-10
1.2000000D 02	4.8380059D-11	2.2654010D-12	2.2654010D-12	1.8603680D-10	1.8603680D-10
1.5000000D 02	4.8379189D-11	2.2653699D-12	2.2653699D-12	2.5399836D-10	2.5399835D-10
1.8000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	3.2195923D-10	3.2195922D-10
2.1000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	3.8991986D-10	3.8991985D-10
2.4000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	4.5788049D-10	4.5788048D-10
2.7000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	5.2584112D-10	5.2584111D-10
3.0000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	5.9380175D-10	5.9380174D-10
3.3000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	6.6176238D-10	6.6176237D-10
3.6000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	7.2972300D-10	7.2972300D-10
3.9000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	7.9768363D-10	7.9768363D-10
4.2000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	8.6564426D-10	8.6564425D-10
4.5000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	9.3360489D-10	9.3360489D-10
4.8000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	1.0015655D-09	1.0015655D-09
5.1000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	1.0695262D-09	1.0695261D-09
5.4000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	1.1374868D-09	1.1374868D-09
5.7000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	1.2054474D-09	1.2054474D-09

CHARACTERISTICS FOR SET NO. = 5

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	2.6207187D-10	1.8095329D-11	1.8095329D-11	2.7142994D-10	2.7142993D-10
6.0000000D 01	5.2413496D-10	2.7454413D-11	2.7454413D-11	9.5467608D-10	9.5467607D-10
9.0000000D 01	7.8619182D-10	3.6813272D-11	3.6813272D-11	1.9186914D-09	1.9186913D-09
1.2000000D 02	7.8617059D-10	3.6812514D-11	3.6812514D-11	3.0230782D-09	3.0230781D-09
1.5000000D 02	7.8615644D-10	3.6812009D-11	3.6812009D-11	4.1274460D-09	4.1274460D-09
1.8000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	5.2318025D-09	5.2318025D-09
2.1000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	6.3361552D-09	6.3361551D-09
2.4000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	7.4405079D-09	7.4405078D-09
2.7000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	8.5448605D-09	8.5448605D-09
3.0000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	9.6492132D-09	9.6492132D-09
3.3000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.0753566D-08	1.0753566D-08
3.6000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.1857919D-08	1.1857919D-08
3.9000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.2962271D-08	1.2962271D-08

4.2000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.4066624D-08	1.4066624D-09
4.5000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.5170977D-08	1.5170977D-08
4.8000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.6275329D-08	1.6275329D-08
5.1000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.7379682D-08	1.7379682D-08
5.4000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.8484035D-08	1.8484035D-08
5.7000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.9588387D-08	1.9588387D-08

CHARACTERISTICS FOR SET NO. = 6

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	1.7279073D-09	1.1519207D-10	1.1519207D-10	1.7278811D-09	1.7278811D-09
6.0000000D 01	4.6075554D-09	1.9197813D-10	1.9197813D-10	6.3354341D-09	6.3354341D-09
9.0000000D 01	6.9111844D-09	2.4956640D-10	2.4956640D-10	1.2958602D-08	1.2958602D-08
1.2000000D 02	6.9109979D-09	2.4956174D-10	2.4956174D-10	2.0445524D-08	2.0445524D-08
1.5000000D 02	6.9108735D-09	2.4955863D-10	2.4955863D-10	2.7932330D-08	2.7932330D-08
1.8000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	3.5419065D-08	3.5419065D-08
2.1000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	4.2905778D-08	4.2905777D-08
2.4000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	5.0392490D-08	5.0392489D-08
2.7000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	5.7879202D-08	5.7879201D-08
3.0000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	6.5365914D-08	6.5365913D-08
3.3000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	7.2852626D-08	7.2852624D-08
3.6000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	8.0339339D-08	8.0339336D-08
3.9000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	8.7826051D-08	8.7826048D-08
4.2000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	9.5312763D-08	9.5312759D-08
4.5000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.0279948D-07	1.0279947D-07
4.8000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.1028619D-07	1.1028618D-07
5.1000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.1777290D-07	1.1777289D-07
5.4000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.2525961D-07	1.2525961D-07
5.7000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.3274632D-07	1.3274632D-07

CHARACTERISTICS FOR SET NO. = 7

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	1.6127551D-11	1.1135647D-12	1.1135647D-12	1.6703471D-11	1.6703471D-11
6.0000000D 01	3.2254679D-11	1.6895139D-12	1.6895139D-12	5.8749649D-11	5.8749649D-11
9.0000000D 01	4.8381366D-11	2.2654476D-12	2.2654476D-12	1.1807407D-10	1.1807406D-10
1.2000000D 02	4.8380059D-11	2.2654010D-12	2.2654010D-12	1.8603680D-10	1.8603680D-10
1.5000000D 02	4.8379189D-11	2.2653699D-12	2.2653699D-12	2.5399836D-10	2.5399835D-10
1.8000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	3.2195923D-10	3.2195922D-10
2.1000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	3.8991986D-10	3.8991985D-10
2.4000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	4.5788049D-10	4.5788048D-10
2.7000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	5.2584112D-10	5.2584111D-10
3.0000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	5.9380175D-10	5.9380174D-10
3.3000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	6.6176238D-10	6.6176237D-10
3.6000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	7.2972300D-10	7.2972300D-10
3.9000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	7.9768363D-10	7.9768363D-10
4.2000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	8.6564426D-10	8.6564425D-10
4.5000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	9.3360489D-10	9.3360489D-10
4.8000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	1.0015655D-09	1.0015655D-09
5.1000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	1.0695262D-09	1.0695261D-09
5.4000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	1.1374868D-09	1.1374868D-09
5.7000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	1.2054474D-09	1.2054474D-09

CHARACTERISTICS FOR SET NO. = 8

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	2.6207282D-11	1.8095422D-12	1.8095422D-12	2.7143134D-11	2.7143134D-11
6.0000000D 01	5.2413839D-11	2.7454593D-12	2.7454593D-12	9.5468157D-11	9.5468157D-11
9.0000000D 01	7.8619697D-11	3.6813513D-12	3.6813514D-12	1.9187032D-10	1.9187031D-10
1.2000000D 02	7.8617573D-11	3.6812755D-12	3.6812755D-12	3.0230972D-10	3.0230972D-10
1.5000000D 02	7.8616163D-11	3.6812250D-12	3.6812250D-12	4.1274723D-10	4.1274723D-10
1.8000000D 02	7.8615452D-11	3.6811997D-12	3.6811997D-12	5.2318360D-10	5.2318359D-10
2.1000000D 02	7.8615452D-11	3.6811997D-12	3.6811997D-12	6.3361959D-10	5.3361959D-10
2.4000000D 02	7.8615452D-11	3.6811997D-12	3.6811998D-12	7.4405558D-10	7.4405558D-10
2.7000000D 02	7.8615452D-11	3.6811998D-12	3.6811998D-12	8.5449158D-10	8.5449157D-10
3.0000000D 02	7.8615452D-11	3.6811998D-12	3.6811998D-12	9.6492757D-10	9.6492757D-10
3.3000000D 02	7.8615452D-11	3.6811998D-12	3.6811998D-12	1.0753636D-09	1.0753635D-09
3.6000000D 02	7.8615452D-11	3.6811998D-12	3.6811998D-12	1.1857996D-09	1.1857995D-09
3.9000000D 02	7.8615452D-11	3.6811998D-12	3.6811998D-12	1.2962355D-09	1.2962355D-09
4.2000000D 02	7.8615452D-11	3.6811998D-12	3.6811998D-12	1.4066715D-09	1.4066715D-09
4.5000000D 02	7.8615452D-11	3.6811998D-12	3.6811998D-12	1.5171075D-09	1.5171075D-09
4.8000000D 02	7.8615452D-11	3.6811998D-12	3.6811998D-12	1.6275435D-09	1.6275435D-09
5.1000000D 02	7.8615452D-11	3.6811998D-12	3.6811998D-12	1.7379795D-09	1.7379795D-09
5.4000000D 02	7.8615452D-11	3.6811998D-12	3.6811998D-12	1.8484155D-09	1.8484155D-09
5.7000000D 02	7.8615452D-11	3.6811998D-12	3.6811998D-12	1.9588515D-09	1.9588515D-09

CHARACTERISTICS FOR SET NO. = 9

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	1.5836709D-08	1.0556908D-09	1.0556908D-09	1.5835361D-08	1.5835361D-08
6.0000000D 01	2.6740500D-08	1.3721736D-09	1.3721736D-09	5.2253326D-08	5.2253326D-08
9.0000000D 01	2.6739111D-08	1.3721386D-09	1.3721386D-09	9.3418009D-08	9.3418007D-08
1.2000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	1.3458217D-07	1.3458216D-07
1.5000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	1.7574632D-07	1.7574631D-07
1.8000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	2.1691048D-07	2.1691046D-07
2.1000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	2.5807464D-07	2.5807461D-07
2.4000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	2.9923880D-07	2.9923876D-07
2.7000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	3.4040296D-07	3.4040291D-07
3.0000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	3.8156711D-07	3.8156705D-07
3.3000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	4.2273127D-07	4.2273119D-07
3.6000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	4.6389543D-07	4.6389533D-07
3.9000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	5.0505959D-07	5.0505947D-07
4.2000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	5.4622374D-07	5.4622361D-07
4.5000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	5.8738790D-07	5.8738774D-07
4.8000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	6.2855206D-07	6.2855188D-07
5.1000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	6.6971622D-07	6.6971601D-07
5.4000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	7.1088038D-07	7.1088014D-07
5.7000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	7.5204453D-07	7.5204427D-07

CHARACTERISTICS FOR SET NO. = 10

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	1.4781319D-10	1.0205414D-11	1.0205414D-11	1.5308121D-10	1.5308120D-10
6.0000000D 01	1.8719390D-10	1.1611435D-11	1.1611435D-11	4.8033395D-10	4.8033394D-10
9.0000000D 01	1.8718567D-10	1.1611141D-11	1.1611141D-11	8.2867260D-10	8.2867259D-10
1.2000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	1.1770068D-09	1.1770068D-09
1.5000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	1.5253411D-09	1.5253411D-09
1.8000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	1.8736753D-09	1.8736753D-09
2.1000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	2.2220096D-09	2.2220095D-09
2.4000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	2.5703438D-09	2.5703438D-09

2.7000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	2.9186780D-09	2.9186780D-09
3.0000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	3.2670123D-09	3.2670123D-09
3.3000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	3.6153465D-09	3.6153465D-09
3.6000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	3.9636808D-09	3.9636807D-09
3.9000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	4.3120150D-09	4.3120150D-09
4.2000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	4.6603492D-09	4.6603492D-09
4.5000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	5.0086835D-09	5.0086835D-09
4.8000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	5.3570177D-09	5.3570177D-09
5.1000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	5.7053520D-09	5.7053519D-09
5.4000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	6.0536862D-09	6.0536862D-09
5.7000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	6.4020204D-09	6.4020204D-09

CHARACTERISTICS FOR SET NO. = 11

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	2.4019552D-09	1.6583709D-10	1.6583709D-10	2.4875564D-09	2.4875564D-09
6.0000000D 01	3.0418801D-09	1.8868453D-10	1.8868453D-10	7.8053807D-09	7.8053807D-09
9.0000000D 01	3.0417464D-09	1.8867976D-10	1.8867976D-10	1.3465845D-08	1.3465845D-08
1.2000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	1.9126238D-08	1.9126238D-08
1.5000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	2.4786630D-08	2.4786630D-08
1.8000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	3.0447023D-08	3.0447023D-08
2.1000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	3.6107416D-08	3.6107415D-08
2.4000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	4.1767809D-08	4.1767808D-08
2.7000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	4.7428201D-08	4.7428200D-08
3.0000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	5.3088594D-08	5.3088593D-08
3.3000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	5.8748987D-08	5.8748985D-08
3.6000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	6.4409380D-08	6.4409378D-08
3.9000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	7.0069772D-08	7.0069770D-08
4.2000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	7.5730165D-08	7.5730162D-08
4.5000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	8.1390558D-08	8.1390555D-08
4.8000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	8.7050950D-08	8.7050947D-08
5.1000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	9.2711343D-08	9.2711339D-08
5.4000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	9.8371736D-08	9.8371731D-08
5.7000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	1.0403213D-07	1.0403212D-07

CHARACTERISTICS FOR SET NO. = 12

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	1.5836709D-08	1.0556908D-09	1.0556908D-09	1.5835361D-08	1.5835361D-08
6.0000000D 01	2.6740500D-08	1.3721736D-09	1.3721736D-09	5.2253326D-08	5.2253326D-08
9.0000000D 01	2.6739111D-08	1.3721386D-09	1.3721386D-09	9.3418009D-08	9.3418007D-08
1.2000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	1.3458217D-07	1.3458216D-07
1.5000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	1.7574632D-07	1.7574631D-07
1.8000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	2.1691048D-07	2.1691046D-07
2.1000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	2.5807464D-07	2.5807461D-07
2.4000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	2.9923880D-07	2.9923876D-07
2.7000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	3.4040296D-07	3.4040291D-07
3.0000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	3.8156711D-07	3.8156705D-07
3.3000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	4.2273127D-07	4.2273119D-07
3.6000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	4.6389543D-07	4.6389533D-07
3.9000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	5.0505959D-07	5.0505947D-07
4.2000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	5.4622374D-07	5.4622361D-07
4.5000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	5.8738790D-07	5.8738774D-07
4.8000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	6.2855206D-07	6.2855188D-07
5.1000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	6.6971622D-07	6.6971601D-07
5.4000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	7.1088038D-07	7.1088014D-07

4.2000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.4066624D-08	1.4066624D-08
4.5000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.5170977D-08	1.5170977D-08
4.8000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.6275329D-08	1.6275329D-08
5.1000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.7379682D-08	1.7379682D-08
5.4000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.8484035D-08	1.8484035D-08
5.7000000D 02	7.8614937D-10	3.6811756D-11	3.6811756D-11	1.9588387D-08	1.9588387D-08

CHARACTERISTICS FOR SET NO. = 18

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	1.7279073D-09	1.1519207D-10	1.1519207D-10	1.7278811D-09	1.7278811D-09
6.0000000D 01	4.6075554D-09	1.9197813D-10	1.9197813D-10	6.3354341D-09	6.3354341D-09
9.0000000D 01	6.9111844D-09	2.4956640D-10	2.4956640D-10	1.2958602D-08	1.2958602D-08
1.2000000D 02	6.9109979D-09	2.4956174D-10	2.4956174D-10	2.0445524D-08	2.0445524D-08
1.5000000D 02	6.9108735D-09	2.4955863D-10	2.4955863D-10	2.7932330D-08	2.7932330D-08
1.8000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	3.5419065D-08	3.5419065D-08
2.1000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	4.2905778D-08	4.2905777D-08
2.4000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	5.0392490D-08	5.0392489D-08
2.7000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	5.7879202D-08	5.7879201D-08
3.0000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	6.5365914D-08	6.5365913D-08
3.3000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	7.2852626D-08	7.2852624D-08
3.6000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	8.0339339D-08	8.0339336D-08
3.9000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	8.7826051D-08	8.7826048D-08
4.2000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	9.5312763D-08	9.5312759D-08
4.5000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.0279948D-07	1.0279947D-07
4.8000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.1028619D-07	1.1028618D-07
5.1000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.1777290D-07	1.1777289D-07
5.4000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.2525961D-07	1.2525961D-07
5.7000000D 02	6.9108113D-09	2.4955707D-10	2.4955708D-10	1.3274632D-07	1.3274632D-07

CHARACTERISTICS FOR SET NO. = 19

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	1.6127561D-11	1.1135647D-12	1.1135647D-12	1.6703471D-11	1.6703471D-11
6.0000000D 01	3.2254679D-11	1.6895139D-12	1.6895139D-12	5.8749649D-11	5.8749649D-11
9.0000000D 01	4.8381366D-11	2.2654476D-12	2.2654476D-12	1.1807407D-10	1.1807406D-10
1.2000000D 02	4.8380059D-11	2.2654010D-12	2.2654010D-12	1.8603680D-10	1.8603680D-10
1.5000000D 02	4.8379189D-11	2.2653699D-12	2.2653699D-12	2.5399836D-10	2.5399835D-10
1.8000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	3.2195923D-10	3.2195922D-10
2.1000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	3.8991986D-10	3.8991985D-10
2.4000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	4.5788049D-10	4.5788048D-10
2.7000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	5.2584112D-10	5.2584111D-10
3.0000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	5.9380175D-10	5.9380174D-10
3.3000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	6.6176238D-10	6.6176237D-10
3.6000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	7.2972300D-10	7.2972300D-10
3.9000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	7.9768363D-10	7.9768363D-10
4.2000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	8.6564426D-10	8.6564425D-10
4.5000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	9.3360489D-10	9.3360489D-10
4.8000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	1.0015655D-09	1.0015655D-09
5.1000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	1.0695262D-09	1.0695261D-09
5.4000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	1.1374868D-09	1.1374868D-09
5.7000000D 02	4.8378753D-11	2.2653543D-12	2.2653543D-12	1.2054474D-09	1.2054474D-09

CHARACTERISTICS FOR SET NO. = 20

2.7000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	2.9186780D-09	2.9186780D-09
3.0000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	3.2670123D-09	3.2670123D-09
3.3000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	3.6153465D-09	3.6153465D-09
3.6000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	3.9636808D-09	3.9636807D-09
3.9000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	4.3120150D-09	4.3120150D-09
4.2000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	4.6603492D-09	4.6603492D-09
4.5000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	5.0086835D-09	5.0086835D-09
4.8000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	5.3570177D-09	5.3570177D-09
5.1000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	5.7053520D-09	5.7053519D-09
5.4000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	6.0536862D-09	6.0536862D-09
5.7000000D 02	1.8718567D-10	1.1611141D-11	1.1611141D-11	6.4020204D-09	6.4020204D-09

CHARACTERISTICS FOR SET NO. = 23

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	2.4019552D-09	1.6583709D-10	1.6583709D-10	2.4875564D-09	2.4875564D-09
6.0000000D 01	3.0418801D-09	1.8868453D-10	1.8868453D-10	7.8053807D-09	7.8053807D-09
9.0000000D 01	3.0417464D-09	1.8867976D-10	1.8867976D-10	1.3465845D-08	1.3465845D-08
1.2000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	1.9126238D-08	1.9126238D-08
1.5000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	2.4786630D-08	2.4786630D-08
1.8000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	3.0447023D-08	3.0447023D-08
2.1000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	3.6107416D-08	3.6107415D-08
2.4000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	4.1767809D-08	4.1767808D-08
2.7000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	4.7428201D-08	4.7428200D-08
3.0000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	5.3088594D-08	5.3088593D-08
3.3000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	5.8748987D-08	5.8748985D-08
3.6000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	6.4409380D-08	6.4409378D-08
3.9000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	7.0069772D-08	7.0069770D-08
4.2000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	7.5730165D-08	7.5730162D-08
4.5000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	8.1390558D-08	8.1390555D-08
4.8000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	8.7050950D-08	8.7050947D-08
5.1000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	9.2711343D-08	9.2711339D-08
5.4000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	9.8371736D-08	9.8371731D-08
5.7000000D 02	3.0417464D-09	1.8867976D-10	1.8867976D-10	1.0403213D-07	1.0403212D-07

CHARACTERISTICS FOR SET NO. = 24

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	1.5836709D-08	1.0556908D-09	1.0556908D-09	1.5835361D-08	1.5835361D-08
6.0000000D 01	2.6740500D-08	1.3721736D-09	1.3721736D-09	5.2253326D-08	5.2253326D-08
9.0000000D 01	2.6739111D-08	1.3721386D-09	1.3721386D-09	9.3418009D-08	9.3418007D-08
1.2000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	1.3458217D-07	1.3458216D-07
1.5000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	1.7574632D-07	1.7574631D-07
1.8000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	2.1691048D-07	2.1691046D-07
2.1000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	2.5807464D-07	2.5807461D-07
2.4000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	2.9923880D-07	2.9923876D-07
2.7000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	3.4040296D-07	3.4040291D-07
3.0000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	3.8156711D-07	3.8156705D-07
3.3000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	4.2273127D-07	4.2273119D-07
3.6000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	4.6389543D-07	4.6389533D-07
3.9000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	5.0505959D-07	5.0505947D-07
4.2000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	5.4622374D-07	5.4622361D-07
4.5000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	5.8738790D-07	5.8738774D-07
4.8000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	6.2855206D-07	6.2855188D-07
5.1000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	6.6971622D-07	6.6971601D-07
5.4000000D 02	2.6739111D-08	1.3721386D-09	1.3721386D-09	7.1088038D-07	7.1088014D-07

1.2000000D 02	4.9492798D-09	2.0621845D-10	2.0621845D-10	1.4229316D-08	1.4229316D-08
1.5000000D 02	6.1865998D-09	2.4746090D-10	2.4746090D-10	2.1034506D-08	2.1034506D-08
1.8000000D 02	7.4239198D-09	2.8870335D-10	2.8870335D-10	2.9076970D-08	2.9076970D-08
2.1000000D 02	8.6609614D-09	3.2993652D-10	3.2993653D-10	3.8356568D-08	3.8356568D-08
2.4000000D 02	9.8980029D-09	3.7116970D-10	3.7116970D-10	4.8873161D-08	4.8873160D-08
2.7000000D 02	1.1135045D-08	4.1240287D-10	4.1240288D-10	6.0626750D-08	6.0626749D-08
3.0000000D 02	1.2372086D-08	4.5363604D-10	4.5363605D-10	7.3617334D-08	7.3617332D-08
3.3000000D 02	1.3609128D-08	4.9486922D-10	4.9486923D-10	8.7844913D-08	8.7844910D-08
3.6000000D 02	1.4846169D-08	5.3610239D-10	5.3610240D-10	1.0330949D-07	1.0330948D-07
3.9000000D 02	1.4845752D-08	5.3608848D-10	5.3608848D-10	1.1939235D-07	1.1939234D-07
4.2000000D 02	1.4845334D-08	5.3607456D-10	5.3607457D-10	1.3547480D-07	1.3547479D-07
4.5000000D 02	1.4844917D-08	5.3606065D-10	5.3606065D-10	1.5155682D-07	1.5155681D-07
4.8000000D 02	1.4844499D-08	5.3604673D-10	5.3604674D-10	1.6763843D-07	1.6763842D-07
5.1000000D 02	1.4844082D-08	5.3603282D-10	5.3603282D-10	1.8371963D-07	1.8371961D-07
5.4000000D 02	1.4843664D-08	5.3601890D-10	5.3601891D-10	1.9980040D-07	1.9980039D-07
5.7000000D 02	1.4843525D-08	5.3601427D-10	5.3601427D-10	2.1588090D-07	2.1588088D-07

CHARACTERISTICS FOR SET NO. = 28

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	2.2497334D-10	4.5744635D-10	4.5744635D-10	6.8616953D-09	6.8616953D-09
6.0000000D 01	4.4994668D-10	9.0739275D-10	9.0739275D-10	2.7334282D-08	2.7334281D-08
9.0000000D 01	6.7492002D-10	1.3573391D-09	1.3573391D-09	6.1305260D-08	6.1305258D-08
1.2000000D 02	8.9989336D-10	1.8072855D-09	1.8072855D-09	1.0877463D-07	1.0877462D-07
1.5000000D 02	1.1248667D-09	2.2572319D-09	2.2572319D-09	1.6974239D-07	1.6974238D-07
1.8000000D 02	1.3498400D-09	2.7071783D-09	2.7071783D-09	2.4420855D-07	2.4420852D-07
2.1000000D 02	1.5747628D-09	3.1570235D-09	3.1570235D-09	3.3217158D-07	3.3217152D-07
2.4000000D 02	1.7996855D-09	3.6068687D-09	3.6068687D-09	4.3362996D-07	4.3362986D-07
2.7000000D 02	2.0246082D-09	4.0567139D-09	4.0567139D-09	5.4858370D-07	5.4858355D-07
3.0000000D 02	2.2495309D-09	4.5065590D-09	4.5065590D-09	6.7703279D-07	6.7703256D-07
3.3000000D 02	2.4744537D-09	4.9564042D-09	4.9564042D-09	8.1897724D-07	8.1897690D-07
3.6000000D 02	2.6993764D-09	5.4062494D-09	5.4062494D-09	9.7441704D-07	9.7441657D-07
3.9000000D 02	2.6993005D-09	5.4060976D-09	5.4060976D-09	1.1366022D-06	1.1366016D-06
4.2000000D 02	2.6992246D-09	5.4059457D-09	5.4059458D-09	1.2987829D-06	1.2987821D-06
4.5000000D 02	2.6991487D-09	5.4057939D-09	5.4057939D-09	1.4609590D-06	1.4609579D-06
4.8000000D 02	2.6990728D-09	5.4056421D-09	5.4056421D-09	1.6231305D-06	1.6231292D-06
5.1000000D 02	2.6989969D-09	5.4054903D-09	5.4054903D-09	1.7852975D-06	1.7852959D-06
5.4000000D 02	2.6989210D-09	5.4053385D-09	5.4053385D-09	1.9474599D-06	1.9474581D-06
5.7000000D 02	2.6988957D-09	5.4052879D-09	5.4052879D-09	2.1096193D-06	2.1096171D-06

CHARACTERISTICS FOR SET NO. = 29

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	1.4623070D-09	9.7489837D-11	9.7489837D-11	1.4623475D-09	1.4623475D-09
6.0000000D 01	2.9245569D-09	1.4622967D-10	1.4622967D-10	5.1181402D-09	5.1181402D-09
9.0000000D 01	4.3868354D-09	1.9497046D-10	1.9497046D-10	1.0236142D-08	1.0236142D-08
1.2000000D 02	5.8491138D-09	2.4371125D-10	2.4371125D-10	1.6816368D-08	1.6816368D-08
1.5000000D 02	7.3113923D-09	2.9245203D-10	2.9245204D-10	2.4858817D-08	2.4858817D-08
1.8000000D 02	8.7736707D-09	3.4119282D-10	3.4119283D-10	3.4363490D-08	3.4363490D-08
2.1000000D 02	1.0235620D-08	3.8992264D-10	3.8992265D-10	4.5330222D-08	4.5330221D-08
2.4000000D 02	1.1697570D-08	4.3865247D-10	4.3865247D-10	5.7758849D-08	5.7758847D-08
2.7000000D 02	1.3159519D-08	4.8738229D-10	4.8738229D-10	7.1649370D-08	7.1649368D-08
3.0000000D 02	1.4621469D-08	5.3611211D-10	5.3611212D-10	8.7001786D-08	8.7001783D-08
3.3000000D 02	1.6083418D-08	5.8484193D-10	5.8484194D-10	1.0381610D-07	1.0381609D-07
3.6000000D 02	1.7545368D-08	6.3357175D-10	6.3357176D-10	1.2209230D-07	1.2209230D-07
3.9000000D 02	1.7544874D-08	6.3355531D-10	6.3355532D-10	1.4109921D-07	1.4109920D-07

4.2000000D 02	1.7544381D-08	6.3353886D-10	6.3353887D-10	1.6010562D-07	1.6010561D-07
4.5000000D 02	1.7543887D-08	6.3352242D-10	6.3352243D-10	1.7911154D-07	1.7911153D-07
4.8000000D 02	1.7543394D-08	6.3350597D-10	6.3350598D-10	1.9811697D-07	1.9811695D-07
5.1000000D 02	1.7542901D-08	6.3348953D-10	6.3348954D-10	2.1712190D-07	2.1712188D-07
5.4000000D 02	1.7542407D-08	6.3347308D-10	6.3347309D-10	2.3612634D-07	2.3612631D-07
5.7000000D 02	1.7542243D-08	6.3346760D-10	6.3346761D-10	2.5513045D-07	2.5513042D-07

CHARACTERISTICS FOR SET NO. = 30

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	8.9989876D-14	6.7494657D-15	6.7494657D-15	1.0124198D-13	1.0124198D-13
6.0000000D 01	1.7997975D-13	1.0498931D-14	1.0498931D-14	3.5996794D-13	3.5996794D-13
9.0000000D 01	2.6996963D-13	1.4248397D-14	1.4248397D-14	7.3117786D-13	7.3117786D-13
1.2000000D 02	3.5995950D-13	1.7997863D-14	1.7997863D-14	1.2148718D-12	1.2148718D-12
1.5000000D 02	4.4994938D-13	2.1747328D-14	2.1747328D-14	1.8110496D-12	1.8110496D-12
1.8000000D 02	5.3993925D-13	2.5496794D-14	2.5496794D-14	2.5197115D-12	2.5197115D-12
2.1000000D 02	6.2990888D-13	2.9245416D-14	2.9245416D-14	3.3408446D-12	3.3408446D-12
2.4000000D 02	7.1987851D-13	3.2994038D-14	3.2994038D-14	4.2744364D-12	4.2744364D-12
2.7000000D 02	8.0984814D-13	3.6742660D-14	3.6742660D-14	5.3204869D-12	5.3204869D-12
3.0000000D 02	8.9981777D-13	4.0491282D-14	4.0491282D-14	6.4789960D-12	6.4789960D-12
3.3000000D 02	9.8978740D-13	4.4239905D-14	4.4239905D-14	7.7499638D-12	7.7499638D-12
3.6000000D 02	1.0797570D-12	4.7988527D-14	4.7988527D-14	9.1333903D-12	9.1333903D-12
3.9000000D 02	1.0797267D-12	4.7987262D-14	4.7987262D-14	1.0573027D-11	1.0573027D-11
4.2000000D 02	1.0796963D-12	4.7985997D-14	4.7985997D-14	1.2012626D-11	1.2012626D-11
4.5000000D 02	1.0796659D-12	4.7984731D-14	4.7984731D-14	1.3452187D-11	1.3452187D-11
4.8000000D 02	1.0796356D-12	4.7983466D-14	4.7983466D-14	1.4891710D-11	1.4891710D-11
5.1000000D 02	1.0796052D-12	4.7982201D-14	4.7982201D-14	1.6331195D-11	1.6331195D-11
5.4000000D 02	1.0795749D-12	4.7980936D-14	4.7980936D-14	1.7770642D-11	1.7770642D-11
5.7000000D 02	1.0795647D-12	4.7980515D-14	4.7980515D-14	1.9210064D-11	1.9210064D-11

CHARACTERISTICS FOR SET NO. = 31

T (HOURS)	Q	W	L	WSUM	FSUM
0.0	0.0	0.0	0.0	0.0	0.0
3.0000000D 01	1.9310228D-10	3.9264179D-10	3.9264179D-10	5.8896268D-09	5.8896268D-09
6.0000000D 01	3.8620456D-10	7.7884611D-10	7.7884611D-10	2.3461945D-08	2.3461945D-08
9.0000000D 01	5.7930684D-10	1.1650504D-09	1.1650504D-09	5.2620393D-08	5.2620392D-08
1.2000000D 02	7.7240912D-10	1.5512547D-09	1.5512547D-09	9.3364971D-08	9.3364966D-08
1.5000000D 02	9.6551140D-10	1.9374591D-09	1.9374591D-09	1.4569568D-07	1.4569567D-07
1.8000000D 02	1.1586137D-09	2.3236634D-09	2.3236634D-09	2.0961251D-07	2.0961249D-07
2.1000000D 02	1.3516725D-09	2.7097808D-09	2.7097808D-09	2.8511418D-07	2.8511414D-07
2.4000000D 02	1.5447314D-09	3.0958983D-09	3.0958983D-09	3.7219936D-07	3.7219929D-07
2.7000000D 02	1.7377902D-09	3.4820157D-09	3.4820157D-09	4.7086807D-07	4.7086796D-07
3.0000000D 02	1.9308490D-09	3.8681331D-09	3.8681331D-09	5.8112031D-07	5.8112014D-07
3.3000000D 02	2.1239079D-09	4.2542506D-09	4.2542506D-09	7.0295606D-07	7.0295581D-07
3.6000000D 02	2.3169667D-09	4.6403680D-09	4.6403680D-09	8.3637534D-07	8.3637499D-07
3.9000000D 02	2.3169016D-09	4.6402377D-09	4.6402377D-09	9.7558442D-07	9.7558395D-07
4.2000000D 02	2.3168364D-09	4.6401074D-09	4.6401074D-09	1.1147896D-06	1.1147890D-06
4.5000000D 02	2.3167712D-09	4.6399771D-09	4.6399771D-09	1.2539909D-06	1.2539901D-06
4.8000000D 02	2.3167061D-09	4.6398468D-09	4.6398468D-09	1.3931882D-06	1.3931873D-06
5.1000000D 02	2.3166409D-09	4.6397165D-09	4.6397165D-09	1.5323817D-06	1.5323805D-06
5.4000000D 02	2.3165758D-09	4.6395861D-09	4.6395862D-09	1.6715712D-06	1.6715698D-06
5.7000000D 02	2.3165541D-09	4.6395427D-09	4.6395428D-09	1.8107581D-06	1.8107565D-06

SYSTEM INFORMATION-UPPER BOUNDS

DIFFERENTIAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	Q	W	L
0.0	0.0	2.00001000D-05	2.00001000D-05
3.00000000D 01	1.00827921D-05	2.00060635D-05	2.00062653D-05
6.00000000D 01	1.01462493D-05	2.00086415D-05	2.00088445D-05
9.00000000D 01	1.01622166D-05	2.00098208D-05	2.00100241D-05
1.20000000D 02	1.01683335D-05	2.00107469D-05	2.00109504D-05
1.50000000D 02	1.01744507D-05	2.00116730D-05	2.00118766D-05
1.80000000D 02	1.01805681D-05	2.00125991D-05	2.00128029D-05
2.10000000D 02	1.01866851D-05	2.00135251D-05	2.00137289D-05
2.40000000D 02	1.01928021D-05	2.00144510D-05	2.00146550D-05
2.70000000D 02	1.01989191D-05	2.00153769D-05	2.00155811D-05
3.00000000D 02	1.02050361D-05	2.00163029D-05	2.00165071D-05
3.30000000D 02	1.02111531D-05	2.00172288D-05	2.00174332D-05
3.60000000D 02	1.02172701D-05	2.00181547D-05	2.00183592D-05
3.90000000D 02	1.02172690D-05	2.00181544D-05	2.00183589D-05
4.20000000D 02	1.02172680D-05	2.00181541D-05	2.00183586D-05
4.50000000D 02	1.02172669D-05	2.00181538D-05	2.00183583D-05
4.80000000D 02	1.02172659D-05	2.00181535D-05	2.00183580D-05
5.10000000D 02	1.02172648D-05	2.00181531D-05	2.00183577D-05
5.40000000D 02	1.02172638D-05	2.00181528D-05	2.00183574D-05
5.70000000D 02	1.02172634D-05	2.00181527D-05	2.00183573D-05

INTEGRAL CHARACTERISTICS-UPPER BOUNDS

T (HOURS)	WSUM	FSUM
3.00000000D 01	6.00092453D-04	5.99915458D-04
6.00000000D 01	1.20031303D-03	1.19960203D-03
9.00000000D 01	1.80058996D-03	1.79898504D-03
1.20000000D 02	2.40089848D-03	2.39803987D-03
1.50000000D 02	3.00123478D-03	2.99676289D-03
1.80000000D 02	3.60159886D-03	3.59515427D-03
2.10000000D 02	4.20199072D-03	4.19321417D-03
2.40000000D 02	4.80241036D-03	4.79094275D-03
2.70000000D 02	5.40285778D-03	5.38834018D-03
3.00000000D 02	6.00333298D-03	5.98540663D-03
3.30000000D 02	6.60383595D-03	6.58214225D-03
3.60000000D 02	7.20436670D-03	7.17854722D-03
3.90000000D 02	7.80491134D-03	7.77460791D-03
4.20000000D 02	8.40545597D-03	8.37031073D-03
4.50000000D 02	9.00600059D-03	8.96565590D-03
4.80000000D 02	9.60654520D-03	9.56064364D-03
5.10000000D 02	1.02070898D-02	1.01552741D-02
5.40000000D 02	1.08076344D-02	1.07495477D-02
5.70000000D 02	1.14081790D-02	1.13434644D-02